

ASTRONOMY

September 1984

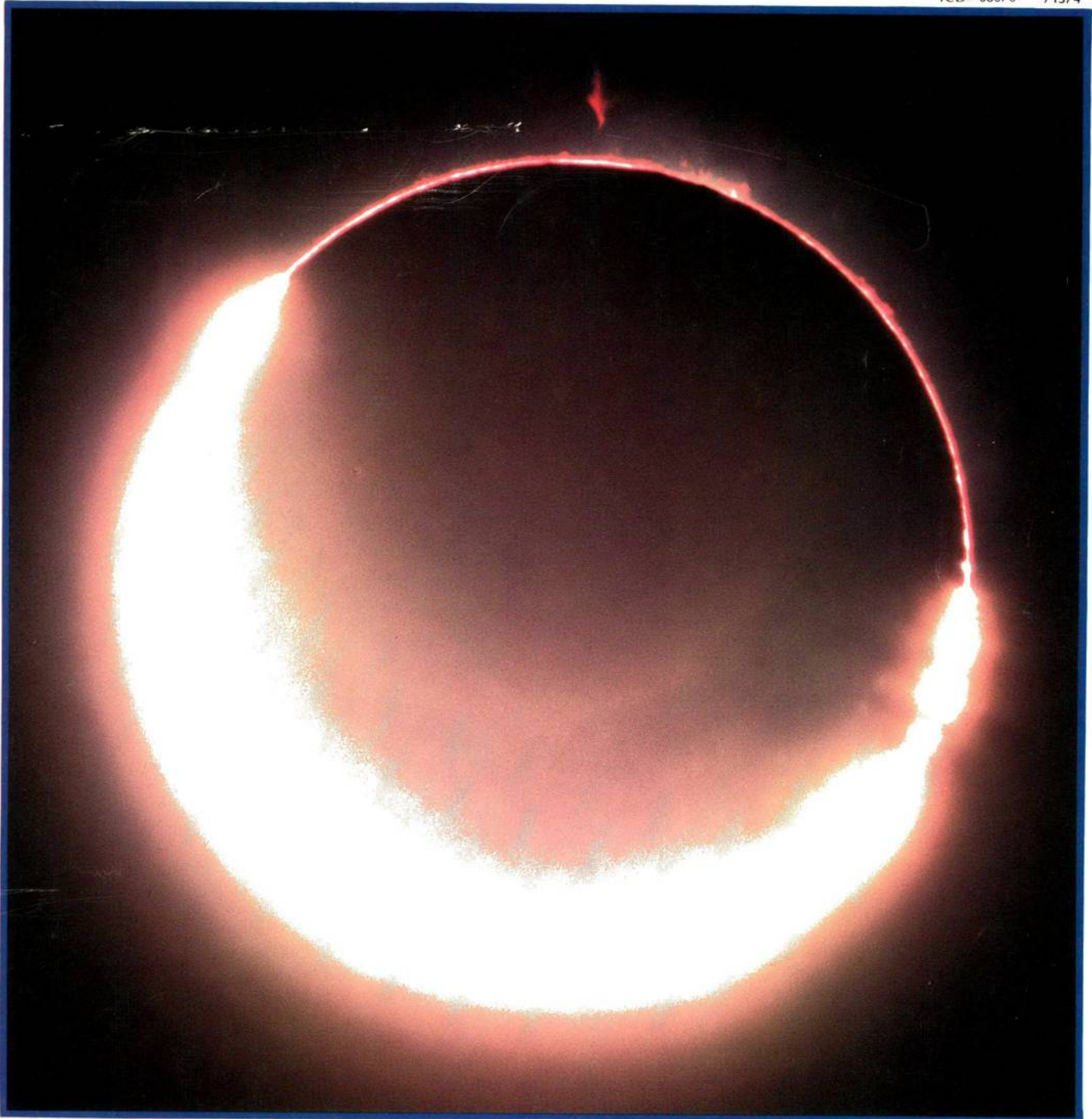
Astronauts Repair Solar Max

Learn the Stars of Autumn

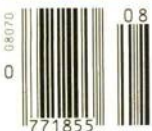
An Interview with the Light-Hearted Astronomer

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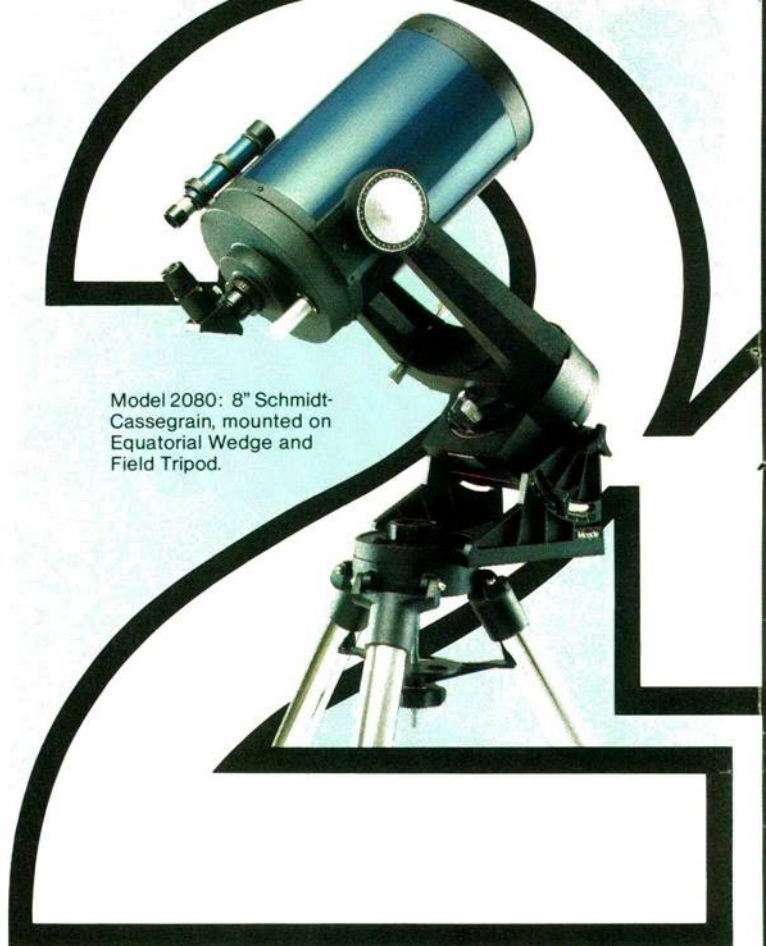
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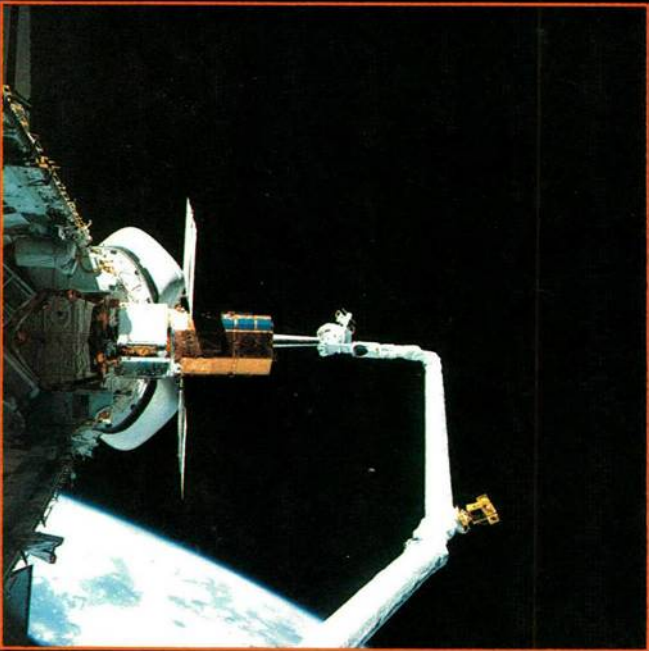
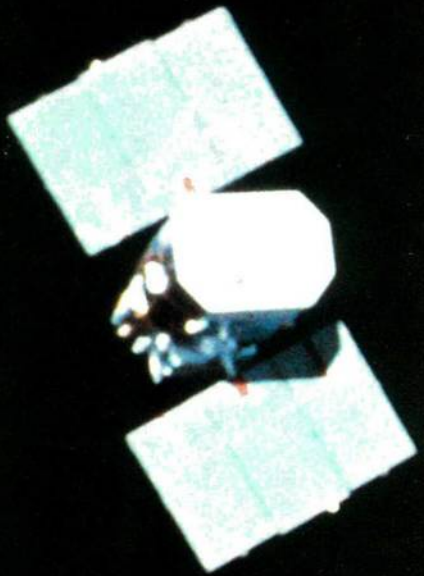
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Cover: The annular solar eclipse on May 30th thrilled observers across the southeastern U.S. Photo by G. Roger Harvey. These pages: Astronaut George Nelson sets out for the crippled Solar Max on what proved to be an unsuccessful attempt to dock with the craft. Solar Max had to be snagged by the Shuttle's arm (inset, below left) before the crew could work on it (inset, upper left). Photos from NASA.

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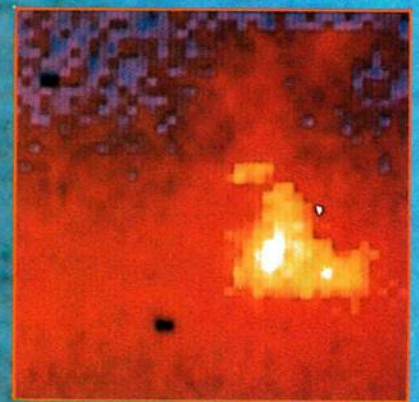
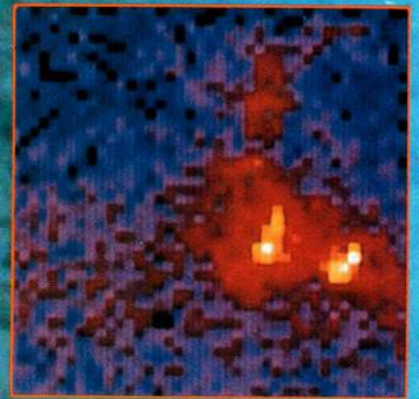


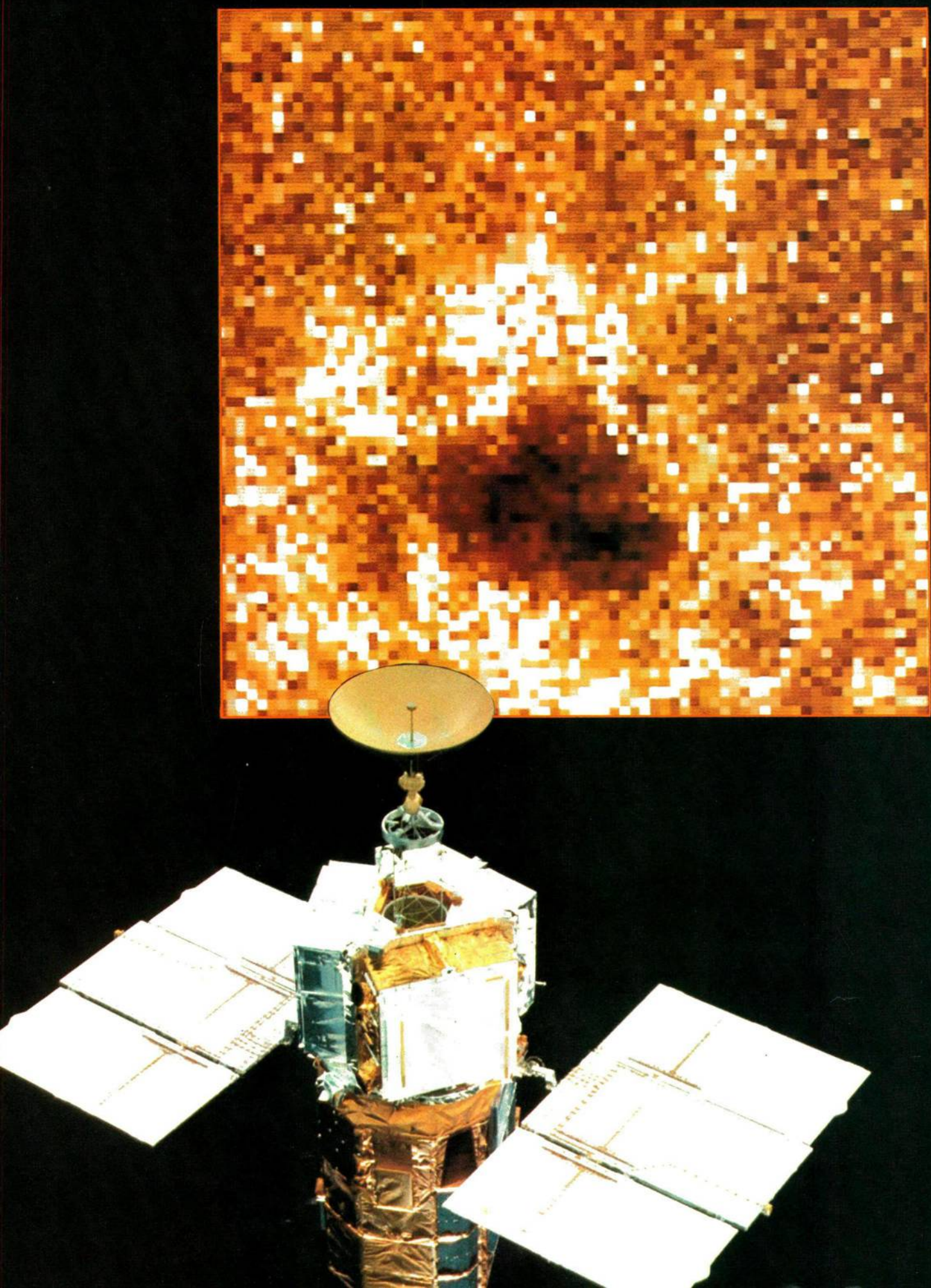
Solar Max Returns

by
Robert
Burnham



Above: Astronaut George Nelson tries in vain to dock with the crippled Solar Maximum Mission spacecraft. Opposite: The first pictures taken by the revived Solar Max show active region 4474 on the Sun in white light (top) and two wavelengths of soft X-rays (middle and bottom). On the day before, this region erupted with the largest solar flare seen since 1978. Background: Four days after the eruption, the craft's white light coronagraph took this picture showing streamers and tendrils in the corona. Shuttle photos are from Johnson Space Center; Solar Max photos from Goddard Space Flight Center.





"It seems to me the satellite's pitching into me a little."
 "It looks like you may have bumped it a little bit, Pinky."
 "Okay, the jaws did not fire that time."
 "... Try again."
 "... Now I did it again and it didn't fire again."
 "Pinky, did they check out okay when you prechecked them?"
 "Yes, they seemed a little stiff... but they worked."
 "Do you want to reattempt it or do you want to come on back? Watch out for the solar array there."
 "... One more try, I've got 1500 psi of fuel."
 "Pinky, you've started that rotation to your left now. We really need to stop that to do a rotating grapple. Is there any way you think you can do it with your hands?"

Pinky — astronaut George Nelson — could not, and in the end Solar Max was snared by the Shuttle's grappling arm after engineers at flight control, making a last-ditch effort, reduced the satellite's wobbly gyrations using the craft's last trickle of battery power.

With the satellite finally brought to rest in the Shuttle's cargo bay, Nelson and fellow crewmember James van Hoften floated out and replaced the balky electronics whose failure in November 1980 had put Solar Max out of action. With repairs complete, the arm hoisted the satellite overboard and set it adrift once again.

The first satellite designed to be retrievable by the Shuttle, Solar Max — the Solar Maximum Mission — was launched in mid-February 1980 (see "A New Look at the Nearest Star," *ASTRONOMY*, May 1981). The mission planners built it to study the Sun, then at maximum activity for this cycle, at wavelengths from the infrared to gamma rays. During the 10 months of its active lifetime, it gave solar physicists their best look ever into the great cataclysms — solar flares — that erupt on the Sun.

At launch, Solar Max carried eight instruments, five with overlapping sensitivities in the X-ray and gamma-ray region of the spectrum, from about 1 nanometer (1000 electron volts) to about 10^{-5} nanometers (10^6 eV). Of these five instruments, two were imagers, the others not. The remaining three instruments operated in the range from about 1000 nanometers in the infrared to 100 nm in the ultraviolet; of them, two were imagers. One instrument, the Hard X-ray Imaging Spectrometer, failed in June 1981 and could not be repaired by the Shuttle crew.

The bulk of the satellite's instruments operate in the high-energy region of the spectrum — only natural, considering the titanic quantities of energy that solar flares produce. To understand how these violent events occur, and how Solar Max can aid our understanding of them, let's take a closer look at what goes on at the Sun's surface.

Heated by thermonuclear reactions in the core of the Sun, hydrogen gas in its outer layers rises the same way that boiling water in a pot does. As it rises, the gas, which is hot enough to be opaque, steadily cools until it reaches a temperature of about 6000° Kelvin, when the hydrogen abruptly becomes transparent. The region where this happens lies about 700,000 kilometers from the Sun's

center and marks the edge of the visible disk. Astronomers call this layer the photosphere.

Viewed with suitable instruments, the apparently bland photosphere turns out to be rich in details which offer clues to internal processes. Deep inside the Sun, the convective motion of the hydrogen occurs in gigantic cells, called supergranulation. By the time the gas reaches the photosphere, however, the cells have become much smaller — in solar terms, that is. Each of the bubbles is still about the size of Texas and about 10 to 15 of them would span the continental U.S. from east to west! They have hot, bright centers and darker edges where the cool gas is descending; each bubble has a lifetime of only a few minutes.

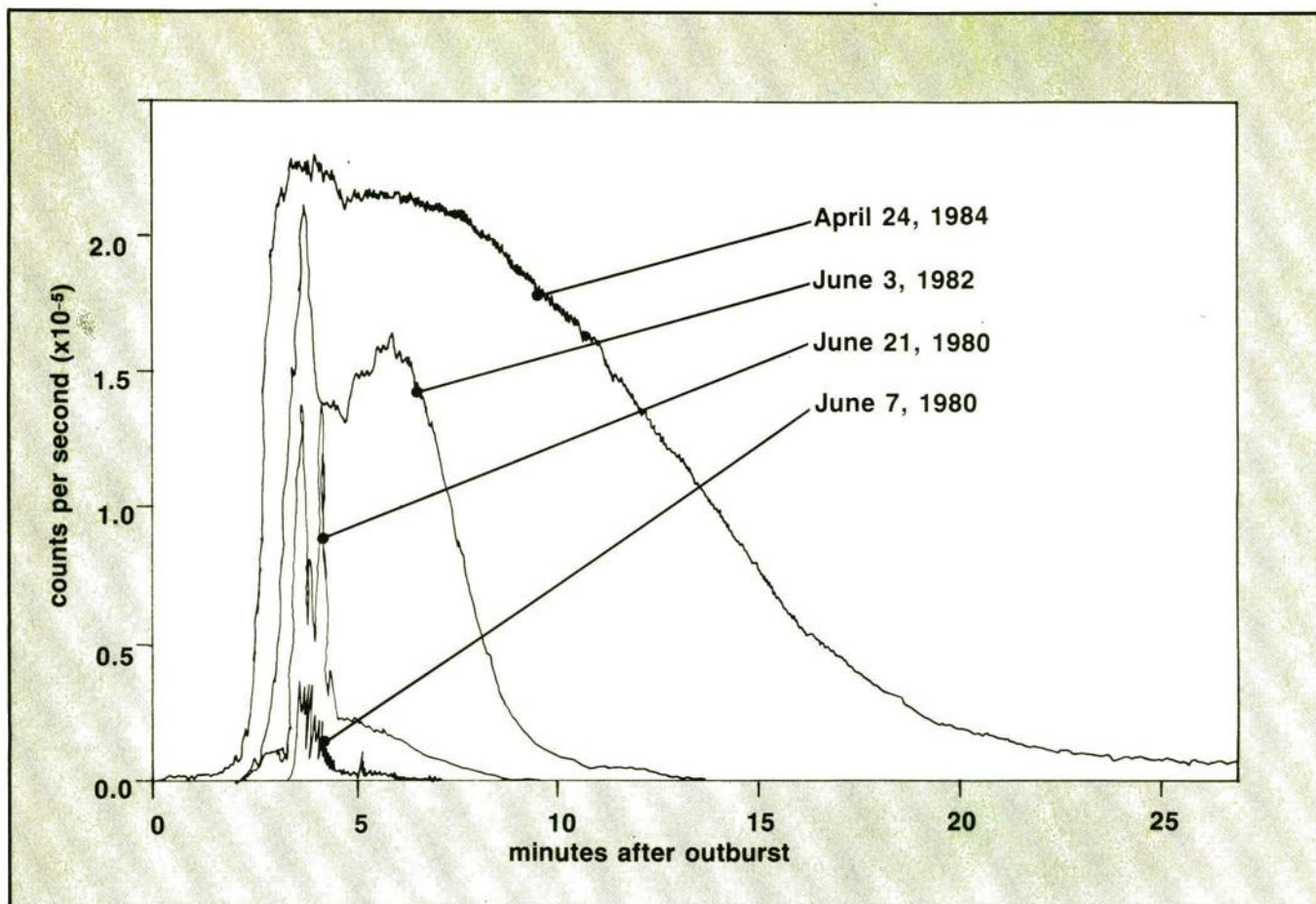
When the photosphere is viewed in hydrogen-alpha light, a few dark curvilinear streaks called filaments snake across it. They often occur near sunspot groups. Generally quiescent features of the chromosphere, they appear dark in projection against the disk but luminous at the limb, where they are called prominences. Another feature of the photosphere is the faculae, bright areas that congregate in active regions near sunspots — the more active the region, the brighter the faculae associated with it. Similar to faculae, but visible only in monochromatic light, are plages — bright regions that occur in the chromosphere. Sunspots are the biggest and most visible feature of the photosphere. They seldom occur singly; a group will usually consist of two or more mature spots with several smaller ones nearby. Locations of intense magnetic disturbances, sunspots begin as tiny dark "pores" — though not all pores develop into full-blown sunspots.

Above the photosphere is a layer about 2000° K cooler and far less dense. Called the chromosphere because it has a strong reddish color when glimpsed during solar eclipses, its light is swamped by that of the photosphere and is normally invisible. On top of the chromosphere lies the corona, the Sun's outer atmosphere: large, extremely tenuous, and very hot. In fact, the corona is so hot — a million degrees or more — that all material in it is ionized. Stripped of all their electrons, the elements in the corona form an electrically conductive plasma.

As the hydrogen gas rises from the center of the Sun, it carries with it not only heat from the interior, but also a magnetic field that has been generated in a manner not yet understood. At the surface, this magnetic field is stretched, twisted, and knotted by the rotation of the Sun and the turbulent surges of the hot gas. The field is elastic and capable of storing up immense quantities of energy, but eventually the limit is reached and the field gives way. The outcome is a solar flare — an incredibly hot, violent jet of gas, particles, and photons. Reaching temperatures of perhaps 20 million degrees Kelvin, flares have truly awesome energies: you could run the United States for a year on about a thousandth the energy of a large one!

The brightest flares are visible in white light, but many more of lesser output can be seen when astronomers observe in the wavelengths of hydrogen-alpha and ionized calcium. The typical flare starts as a brightening in the Sun's photosphere, often in or near a plage. Suddenly there is a brilliant burst of ultraviolet light that erupts upward. When this hits the chromosphere, it sets off a blast of hard X-rays (those with energies greater than 10,000 eV). After a few minutes, the hard X-ray flux declines to nearly normal as the electrons producing it collide with the gas in the overlying corona and slow down. Then the heated coronal gas, electrically conductive and

Successfully repaired, Solar Max floats free of the Shuttle to begin its renewed mission. Inset image, taken by the ultraviolet spectrometer, shows a sunspot (dark oval) surrounded by brighter regions of increased temperature.



functioning like a natural particle accelerator, sends out a surge of soft X-rays, which peaks a few minutes later. At first, the UV flux declines along with the hard X-rays, but then it rises again to coincide with the soft X-rays. After about 20 minutes, everything returns to normal and the eruption is over.

But the flare's work is not yet done. Racing away from the Sun at speeds up to 1000 kilometers per second (and individual protons can be traveling at nearly the speed of light) is a blast wave containing perhaps 10 billion tons of solar material. A tiny fraction of this may encounter the Earth. When it does, the particles slam into the ionosphere, compressing and distorting it wildly. Radio reception is disrupted, phone lines crackle with static from transient currents generated in them, and auroras brighten the night skies with their cold, eerie flicker.

Fortunately for us here on Earth, the radiation is stopped almost entirely by the atmosphere. Space crews, however, have little or no protection, and this is one reason why understanding the mechanism, dynamics, and content of solar flares is so urgent. On the other hand, given that solar activity is now on the downswing, was there any point in reviving Solar Max? Shouldn't we have sent up another when peak activity came due again? Was this \$50 million service call just a bravura stunt?

The answer, emphatically, is "no." In the first place, flares that occur during solar minimum are rarer but more powerful, and therefore can tell us more about themselves. Second, given that nothing unforeseen happens, the repaired Solar Max should now operate well into the next solar maximum, due in 1991. This would mean that, except for a three-and-a-half-year hiatus, Solar Max would

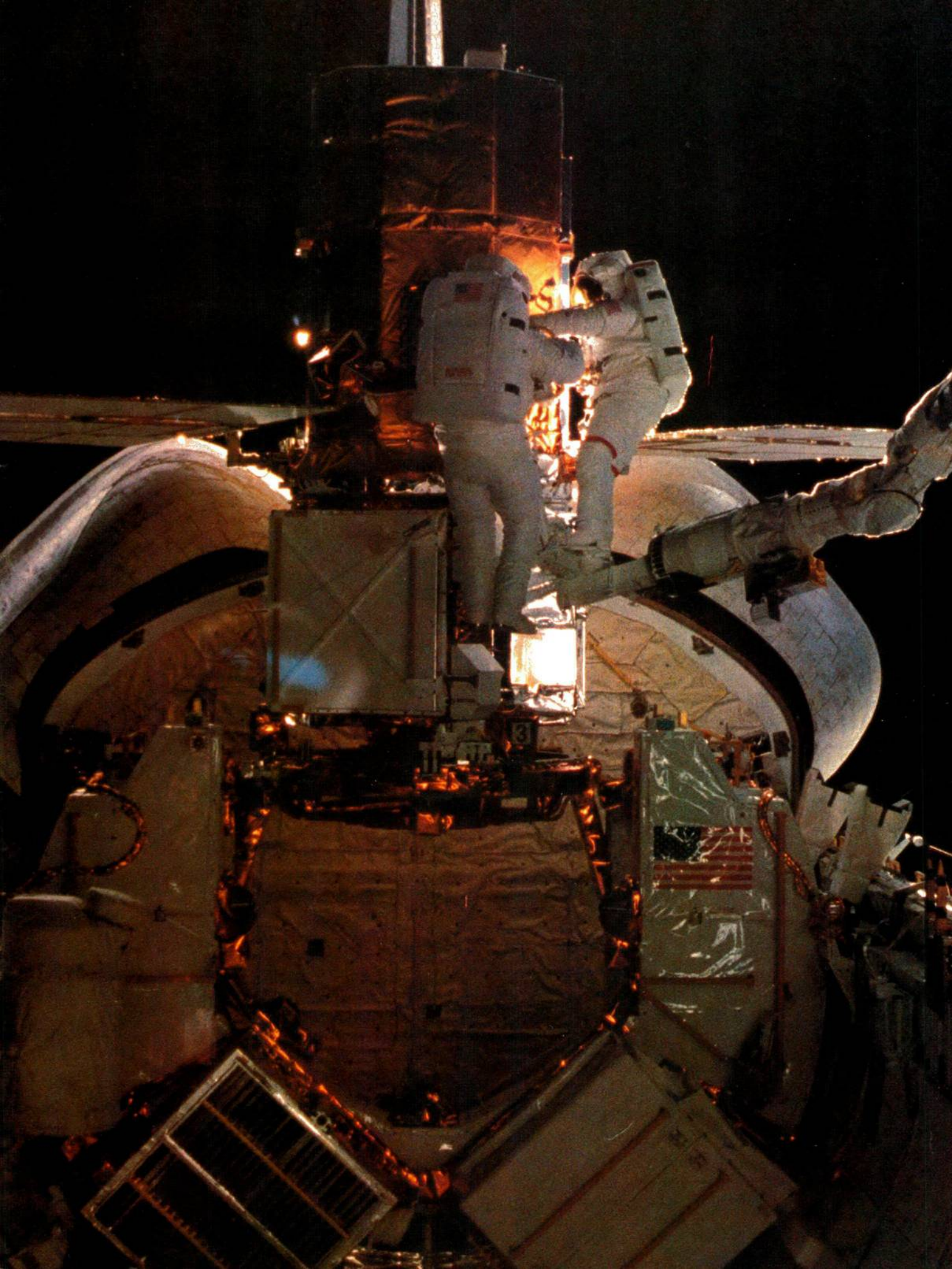
Right: Astronauts George Nelson (right) and James van Hoften work on Solar Max in the Shuttle's cargo bay. Above: The hard X-ray flux from the big flare caught by Solar Max was much stronger than several recent others.

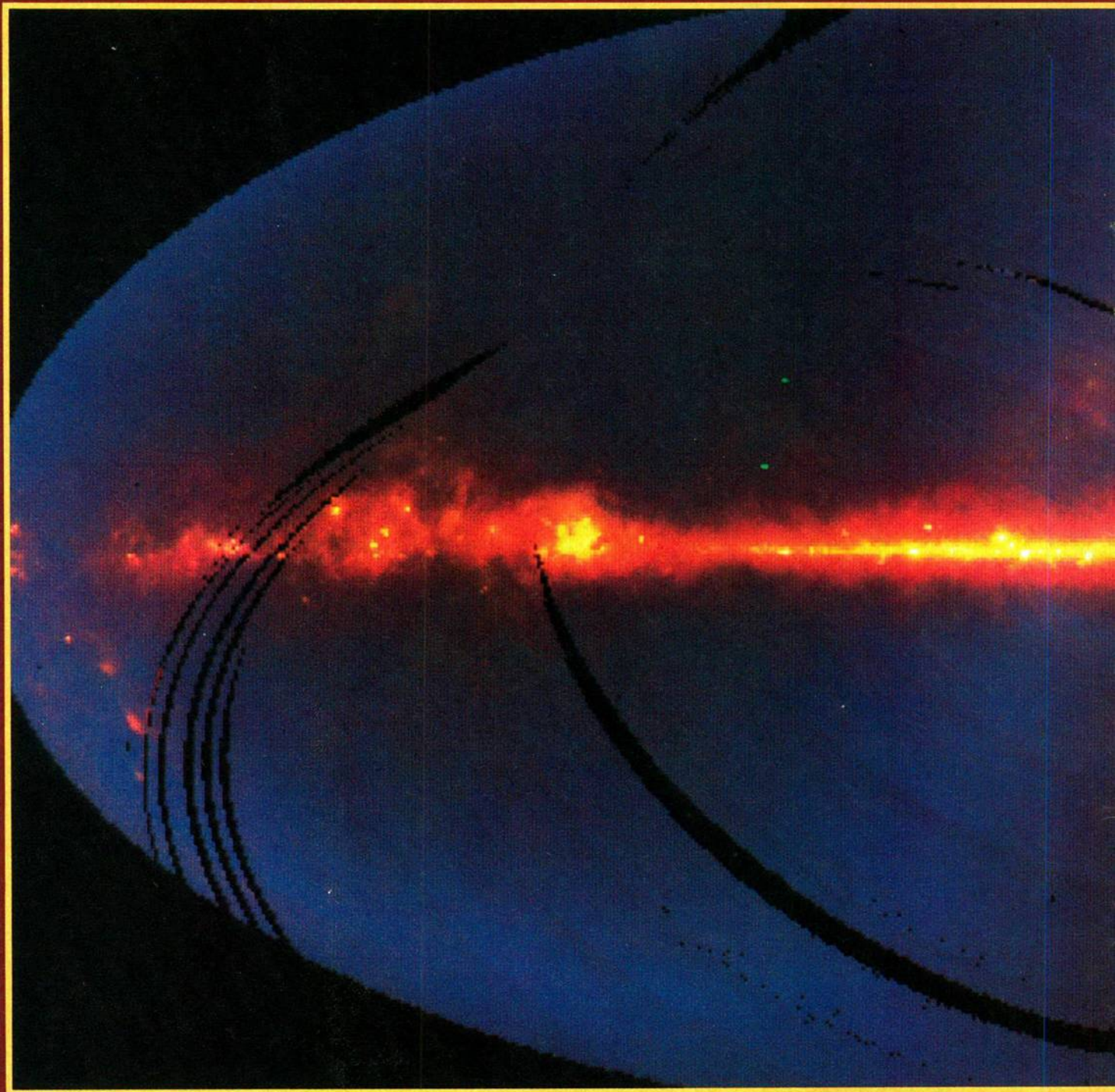
have kept the Sun under continuous observation for at least one entire cycle. A record like this is extremely important for establishing a baseline on the Sun's activity. Our current model for how flares operate is undoubtedly oversimple. For example, the precise mechanism may well vary over the course of the solar cycle — as may the distribution of energy in the flare, a matter of prime concern for the health of astronaut crews. Rejuvenating Solar Max means that the theorists will get the mountain of data they need to develop models for flare eruptions — and also explore how some of the still-unknown processes within the Sun operate.

In any case, the repair was certainly well-timed: the "new" Solar Max was still being checked out when the largest solar flare seen since 1978 burst forth on April 24th. Project scientists were able to halt their tests and go into action, capturing the priceless data rapidly.

Nor will the craft concentrate wholly on the Sun — when Comet Halley swings by in 1986, it will be invisible for a certain period when it is near the Sun. Solar Max will be the only observer, satellite or ground-based, able to keep it in view during the 2½ months straddling perihelion.

With its new lease on life, the Solar Maximum Mission is entering what promises to be a long and fruitful period. If all goes well, the three years during which the satellite was crippled will dwindle to a negligible portion of the entire mission — a colicky infancy soon outgrown.



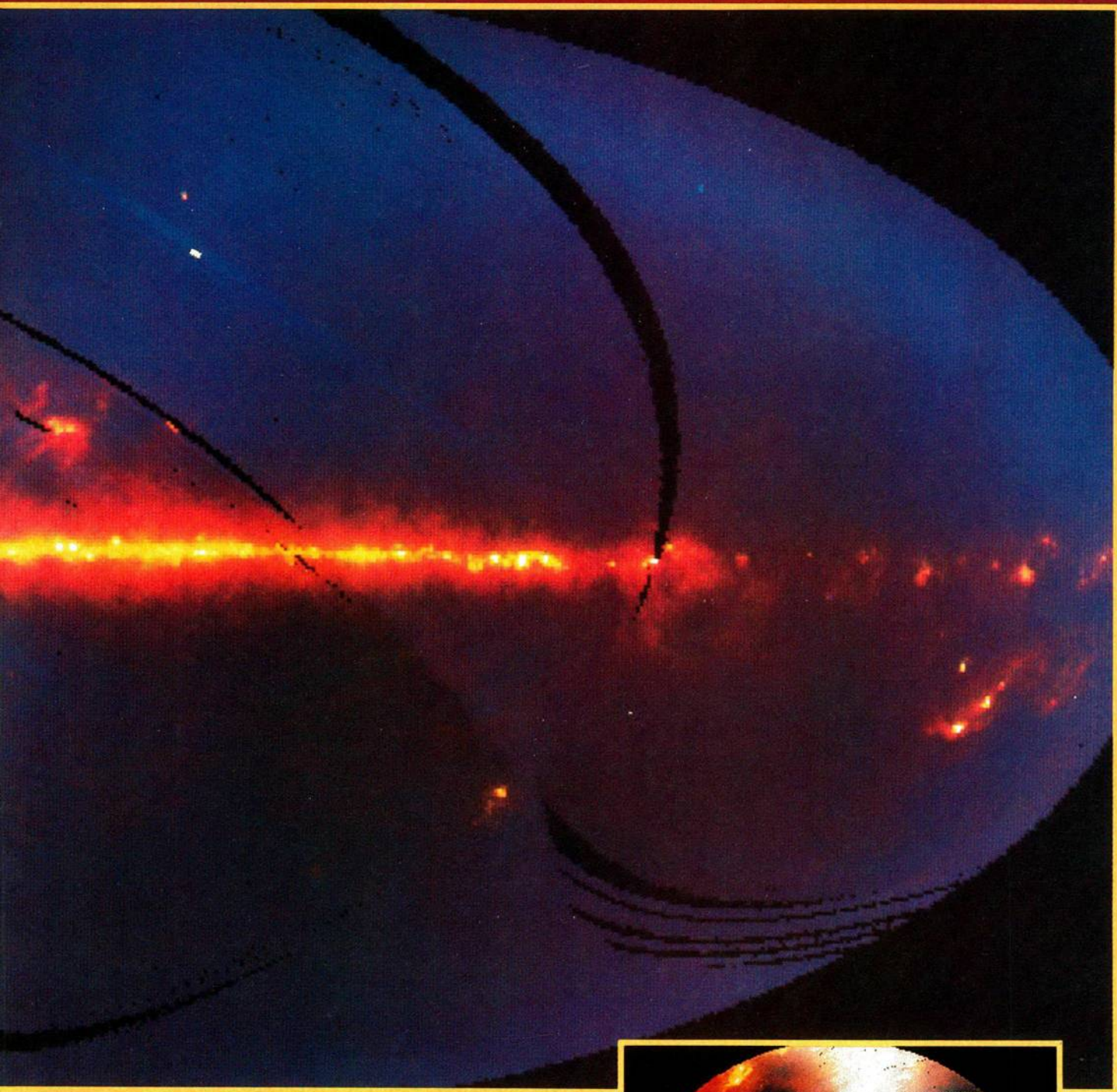


IRAS Views the Galaxy

During its operational lifetime of nearly a year, the Infrared Astronomy Satellite — IRAS — conducted a survey of the whole sky at four infrared wavelengths. Project scientists have compiled the scan data into the composite all-sky view seen above. The galactic plane extends from side to side; the galactic center is in the middle of the photo, and the anticenter lies at

the two ends. The horizontal yellow and red line marks radiation from cool dust in the galactic plane (notice the knots and streamers).

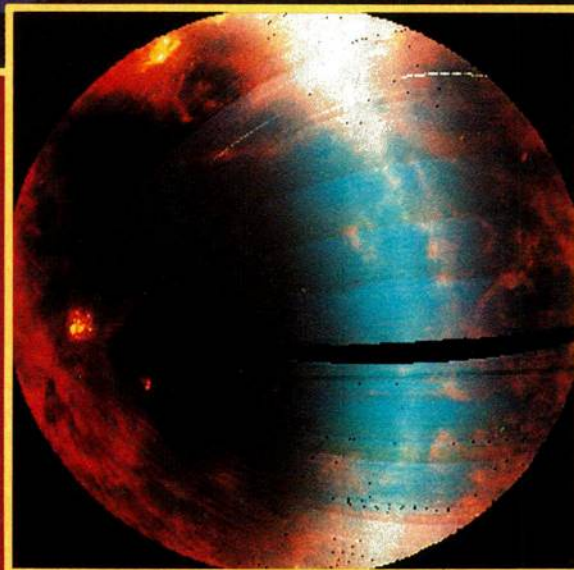
The region above the galactic plane in the center is a large dust region near Rho Ophiuchi. It lies between us and the galactic center and appears out of the plane due to perspective. At the far right and below the plane are Orion and Taurus — again moved out of the plane by our perspective. The Perseus association lies at the extreme left and below the plane. The Large Magellanic Cloud is the small dot below the plane and about halfway between the Rho



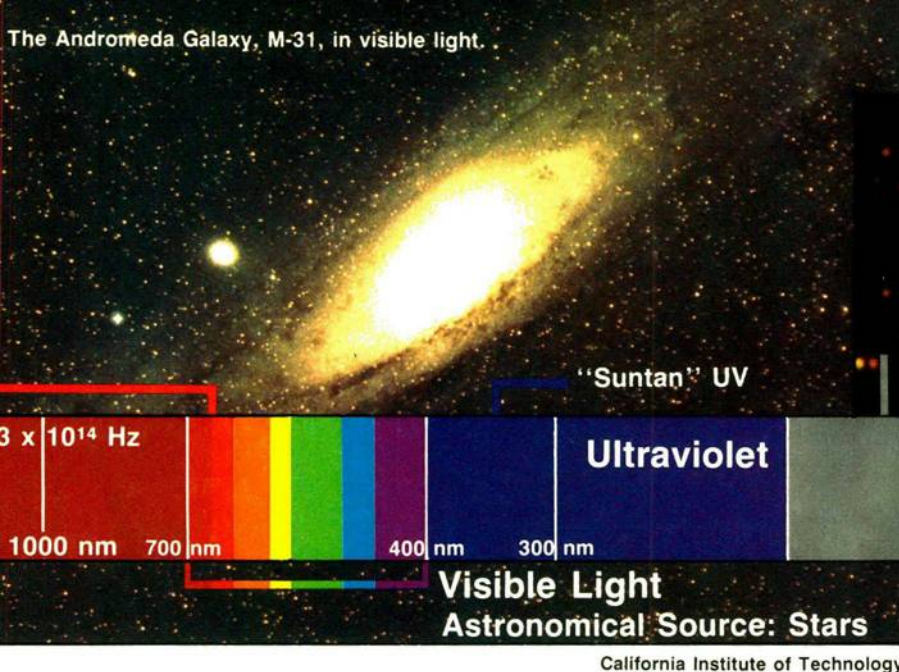
Ophiuchi and the Orion regions.

Looking toward shorter wavelengths and warmer material, we see a large curving bluish swath that describes a giant recumbent S. This follows the plane of the ecliptic and is Sun-warmed dust within our own solar system. (The dark lines are regions unscanned by IRAS, or areas where the data haven't been reduced yet.)

At right is a view centered on the south galactic pole. The pale swath is the warm ecliptic dust, but behind it you can make out reddish billows that reveal the cold "cirrus" found at latitudes away from the galactic plane.



photos courtesy JPL/NASA



Courtesy Lou Frank, University of Iowa

Satellite-borne instruments reveal hot, ultraviolet-emitting stars, scattered solar UV (diffuse glow) and the fluorescing terrestrial atmosphere (auroral oval and equatorial airglow) between 118 and 165 nm.

Spectral Visions, Part 2

The Short Wavelengths and Beyond

by
David J. Darling

Last month we looked at the universe through radio, infrared, and optical eyes — we saw visions of the cosmos at the long wavelengths of the electromagnetic spectrum. Here we examine high-energy, short-wavelength radiation, as well as spectral visions of a totally different kind.

Countless gamma-ray, X-ray, and ultraviolet photons sail the cosmic seas. They come from the strangest regions we can imagine: the maelstrom of a quasar's core, the torrid zone of exchanging gases in a close binary star system, the natural cyclotron of a star wreck. They travel for thousands, millions, even billions of years on their great odysseys to Earth. Yet every one of them is stopped just milliseconds short of planet-fall by the gases that surround our world. Earth's atmosphere, it turns out, is totally opaque to all radiation beyond a wavelength of 0.3 micrometer.

Of course, without this shield there would be no terrestrial life — and certainly no human astronomers to ponder the nature of the universe! On the other hand, the same atmospheric filters that protect us also rob us of an important view of the cosmos beyond the violet end of the visible spectrum.

Until quite recently, it seemed that astronomy would suffer little as a result of our short-wavelength blindness. Even after the dawn of the satellite era, astronomers were forecasting only modest prospects for space-borne observation — for example, monitoring ultraviolet light from hot stars and detecting gamma radiation that might

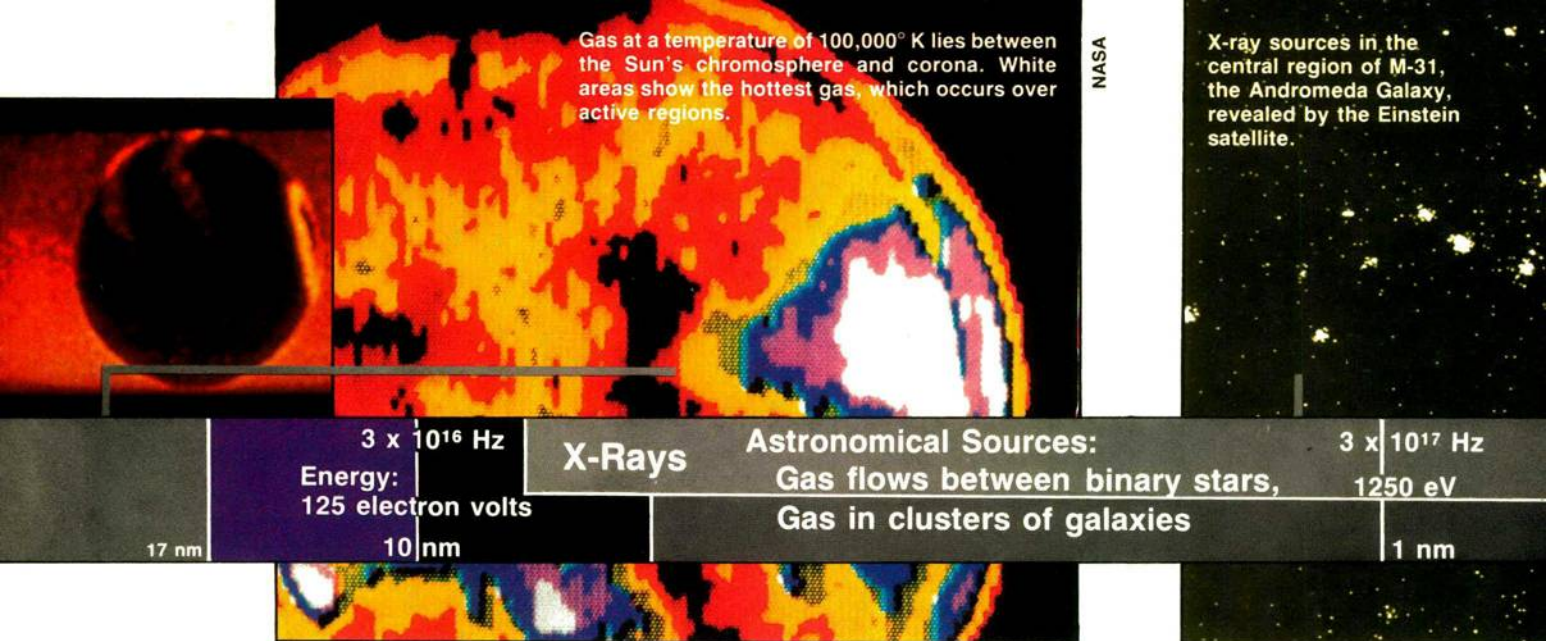
elucidate the origin of the mysterious cosmic rays. At ground level, optical astronomy seemed set to continue in its dominant role, supported by the vigorous new radio astronomy.

The Stars of Ultraviolet

Ultraviolet from about 300 to 400 nanometers actually makes its way through our atmospheric blanket and reaches the surface. But in order to detect shorter wavelengths, we have to lift our instruments up to the edge of space. Our first clear, sustained view of the ultraviolet cosmos came in December 1968, with the launch of NASA's second Orbiting Astronomical Observatory (OAO-2).

Observations from OAO-2 and later craft, like OAO-3 (also known as "Copernicus") and the International Ultraviolet Explorer, showed that stars comprise the main objects in the ultraviolet sky. Prime sources include hot subdwarfs (stars faint at visible wavelengths but bright in the ultraviolet), the central stars of planetary nebulae, and the youthful OB-type stars that seem to expel matter at a furious rate. Much to the surprise of astronomers, these observations revealed that stellar surface temperatures ranged higher than previously seemed possible — some stars have surface temperatures in excess of 100,000° Kelvin. For comparison, the surface of our Sun has a temperature of only 6,000° K.

Objects within our own Solar System have also been targets for ultraviolet observation. These include the Sun, which pours out ultraviolet from its intensely hot lower



atmosphere (called the chromosphere), and some of the planets — especially Mars and the gas giants Jupiter, Saturn, Uranus, and Neptune. In addition, ultraviolet observations of comets and asteroids help reveal their composition and may eventually expose a link between these apparently different vagabonds of the solar system.

Ultraviolet observations also reveal the secrets of the interstellar medium. As its name suggests, the interstellar medium is a tenuous matrix of gas and dust that fills the void between stars. When electromagnetic radiation passes through a cool gas, some of the gas atoms absorb it. An optical spectrum of a star behind a cool gas cloud would thus show a continuum — a rainbow-like spread of color — containing discrete dark lines. Every element absorbs radiation at a certain characteristic wavelength, so astrophysicists can determine the nature of the absorbing gas cloud by comparing the dark lines in the star's spectrum to laboratory measurements of different gases. It turns out that very few atoms and ions display absorption lines at optical wavelengths — it's in the ultraviolet region that we find most of these telltale atomic signatures.

On another front, ultraviolet measurements supply us with clues to the powerful "engines" within active galaxies and quasars. These observations favor theories that invoke supermassive black holes as the inner power source. Take the case of the nearest Seyfert galaxy, NGC-4151. Recent ultraviolet studies suggest that a very compact, massive object lies at the galaxy's heart. Cloud motions and structure within the quasar-like core of NGC-4151 — all deduced from spectroscopic observations in the ultraviolet — hint at the presence of a central black hole containing from 50 to 100 million solar masses of material.

International Ultraviolet Explorer (IUE), which provided this data, is still operational. In fact, IUE has been one of the great success stories of space-borne astronomy since its launch in January 1978 (see "The New Era in Ultraviolet Astronomy," *ASTRONOMY*, October 1978). Co-sponsored by Britain's Science Research Council, which supplied the instrumentation (a 45-centimeter telescope with associated spectrograph), NASA, and the European Space Agency, IUE continues to provide a

wealth of data from 110 to 320 nm wavelength. What have we learned from IUE? It has given us evidence that magnetic fields are at least partially responsible for the unexpected regions of hot gas around many stars, evidence in support of the "gravitational lens" theory of multiple quasars, and, perhaps most importantly, the discovery of a massive corona of hot gas around our own Galaxy. (See "A Bigger and Better Milky Way Galaxy," *ASTRONOMY*, January 1984.)

A Soviet ultraviolet/X-ray satellite named Astron has already joined IUE in space. In the future, we can expect contributions from the Shuttle, too. Equipped with the Astro payload — a package of ultraviolet telescopes and cameras — the Shuttle's first ultraviolet mission is scheduled for early 1986. (See "Astronomy from the Shuttle," *ASTRONOMY*, April 1984.)

With X-Ray Eyes

Looking back, it seems ironic that cosmic X-rays were considered the least significant of all the electromagnetic couriers. Thirty years ago, astronomers pictured the X-ray sky as a rather barren wilderness, lit here and there by feeble X-ray emissions from nearby stars. X-rays from the Sun were first detected in 1948, but they only confirmed what most scientists had predicted. Solar X-rays were very weak, accounting for only one-millionth of the Sun's total radiation output. This high-energy radiation came not from the body of the Sun itself, but from the corona — its extremely hot, tenuous outer atmosphere. The future for X-ray astronomy seemed bleak indeed.

But then, quite suddenly, the outlook changed. In 1962, a team from American Science and Engineering, headed by Riccardo Giacconi, sent a very sensitive detector on a brief, sub-orbital rocket flight. This mission resulted in the discovery of the first X-ray source beyond the solar system, later christened Scorpius X-1. The exciting part of this discovery was that the detector lacked the sensitivity required to pick up weak X-rays from even the nearest Sun-like stars. Clearly, Sco X-1 was something quite new and powerful. All reasonable assumptions showed that, in X-rays alone, Sco X-1 surpassed the total energy output of the Sun by a thousandfold!

There was another mystery, too — a second source of X-rays disclosed during the same historic flight. But instead of recording a discrete source like Sco X-1, the

Skylab detected X-rays from 0.2 to 6 nm emitted by the million-degree gas in the Sun's corona.

Energy of typical dental X-ray — 0.07 MeV

3×10^{18} Hz

12,500 eV

0.1 nm

instrument detected X-rays throughout the sky. The Earth, it seemed, was being bombarded by a steady stream of X-rays coming uniformly from every direction in space — a cosmic X-ray background.

Taken together, these discoveries had an immediate and dramatic effect on X-ray astronomy. What had before seemed like a fruitless quest for faint emissions from normal stars turned into a fascinating search for whole new classes of cosmic phenomena. Yet the problem of detection still remained. Satellite technology was in its infancy; only rarely could the X-ray detection equipment determine a source's location well enough for identification at other wavelengths. Throughout the 1960s, sub-orbital low-resolution observations continued, providing us with brief, tantalizing glimpses of the X-ray sky. In all, astronomers found about 30 X-ray objects within the Milky Way; two others, famous for other reasons, lay beyond our home Galaxy.

The galactic sources seemed to congregate about the plane of the Milky Way — a clue that they were located in the spiral arms. Unfortunately, only a handful of these sources could be identified with known objects at visual wavelengths. The optical counterpart of Sco X-1, for instance, turned out to be a faint blue star. Taurus X-1 is better known as the Crab Nebula, a young supernova remnant. Of the two identifiable extragalactic sources, one coincided with M-87, a remarkable giant elliptical galaxy in Virgo; the other matched 3C 273, the brightest and first-known quasar.

The next act of the X-ray drama began in December 1970 with the launch of Uhuru, the first satellite specifically designed for X-ray observing. Uhuru's prime task was to survey the entire sky at X-ray wavelengths, allowing us to compile the first reasonably comprehensive catalog of cosmic X-ray sources. In fact, Uhuru became one of our most penetrating eyes on the cosmos in the early 1970s. It pinpointed over 100 new X-ray sources, identifying their positions accurately enough so that many could be matched with objects at visible wavelengths. Uhuru's data showed that many galactic X-ray sources (including Sco X-1) are associated with binary star systems in which one of the components is a "collapsed" object — a white dwarf, a neutron star, or perhaps a black hole. It also showed that entire clusters of galaxies can emit

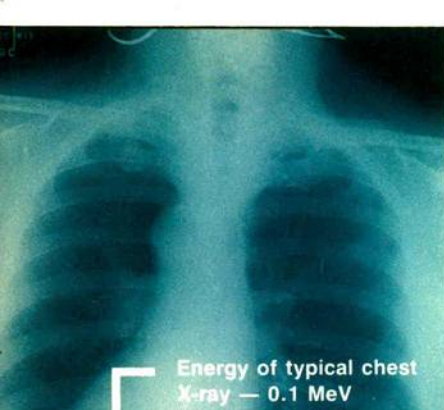
copious amounts of X-rays.

It turned out that many X-ray sources vary their output, particularly those in binary systems. Some — the so-called "X-ray bursters" — flare up spectacularly for brief periods before returning to their dormant state. Others release X-rays continuously, but with variable intensity — fluctuations could occur over periods as short as a few milliseconds. In both cases, it became clear that the emitting region was probably both very hot and very compact. Accretion disks became a favored model for the production of rapidly varying X-rays. These hot whirlpools of gas and dust form around the collapsed member of a binary system when its normal companion hurls material from its surface.

In the 1970s, excitement grew as the new X-ray results filtered through the international astronomical community. Inundated with observational data, theorists performed astounding mental gymnastics to account for the behavior of the X-ray sources. Important discoveries and theoretical possibilities seemed to emerge on a daily basis. The flood of X-ray data continued as other probes superseded Uhuru. These included the third Orbiting Astronomical Observatory (OAO-3), the Dutch-equipped Astronomy Netherlands Satellite (ANS), Britain's Ariel V, the third of the Small Astronomical Satellite series (SAS-3), and, in 1977, the first of the High-Energy Astrophysical Observatories (HEAO-1). All contributed to an enormous increase in our knowledge of the universe at X-ray wavelengths.

The nature of the emission from binary systems grew clearer. In at least one object — the X-ray source Cygnus X-1 — it appeared that we might be looking at a black hole in orbit around a luminous blue supergiant. The 1970s threatened to become the "Decade of the Black Hole" as evidence mounted that Cyg X-1 could be an example of what many theorists had suggested was the inevitable, devastating end-point for some massive stars.

On another front, Ariel V solved the mystery of the emissions from clusters of galaxies. Most of the cluster X-rays weren't coming from the constituent galaxies themselves, but from an intensely hot gas that inhabited the intergalactic voids — conclusive evidence for an intergalactic medium. This discovery was of major cosmological importance as it provided evidence of



Energy of gamma-rays emitted when
electrons and positrons collide — 0.511 MeV

Energy of gamma-rays from cobalt-60
used in cancer therapy — 1 MeV

3×10^{19} Hz
0.125 million eV
0.01 nm

Gamma Rays

**Astronomical Source: Atoms of
interstellar gas struck by high-
velocity particles (cosmic rays)**

3×10^{20} Hz
1.25 MeV
0.001 nm

“hidden” mass in the universe, a key factor in cosmological predictions.

Ariel V went on to make other significant contributions to X-ray astronomy in the mid-1970s. Its sky surveys clearly showed that Seyfert galaxies — unusual spiral galaxies with seemingly star-like nuclei at visual wavelengths — commonly emit X-rays, suggesting a link between quasars, active galaxies, and Seyferts. (See “The Quest for Black Holes,” *ASTRONOMY*, July 1983.)

Another avalanche of X-ray data followed the launch of the second High-Energy Astrophysical Observatory (HEAO-2), nicknamed “Einstein,” in 1978. One of the most sophisticated satellites ever put into orbit, Einstein carried the largest imaging X-ray telescope ever built. A problem with earlier X-ray satellites was their relatively low resolution; although they could detect and locate sources, they could not resolve their structure in any great detail. Einstein, however, gave angular resolution of X-ray objects on par with that of optical observations made at ground level. For the first time, our X-ray eyes matched the resolution of our vision in the optical spectrum.

During its three years of operation, the Einstein observatory revolutionized what was already a field of explosive growth. Among other things, it revealed at least two totally distinct classes of *normal* stars as being unexpectedly powerful X-ray emitters. The coronal regions of both hot young stars — O, B, and A types — and those of much cooler, middle-aged M-type dwarfs, spewed out X-rays in astonishing amounts. In particular, the cool dwarfs were fully one-tenth as bright in the X-ray region as they were in the visible. Astrophysicists looked sadly at their tattered theories of stellar atmospheres and scratched their heads (see “X-rays from Stars,” *ASTRONOMY*, September 1983). Einstein showed us the gleaming X-ray knots and tendrils in supernova remnants, picked out the brightest X-ray sources in our neighboring galaxy, M-31 in Andromeda, and showed them to be similar to those in our own Milky Way. It probed further the bubbling cauldron of hot gas that provides the only landmark in the lonely space between the galaxies.

Einstein also searched the quasars for X-rays. Previously, only three quasars had been positively identified as X-ray sources; Einstein found many more. In fact, every quasar Einstein observed proved to be a source

of X-rays. What’s more, Einstein found many other extragalactic X-ray sources at positions corresponding to no previously known objects. Were these distant quasars so faint that their visual images had never been seen? Possibly. In fact, many astronomers today believe that the unidentified X-ray sources found by Einstein are indeed very remote cosmic objects. Some have even suggested that they might be responsible for the seemingly uniform cosmic X-ray background mentioned earlier. If this is the case, then future X-ray craft, with instruments of still higher resolution, should see the “graininess” of the background emission — individual sources in small regions of the sky.

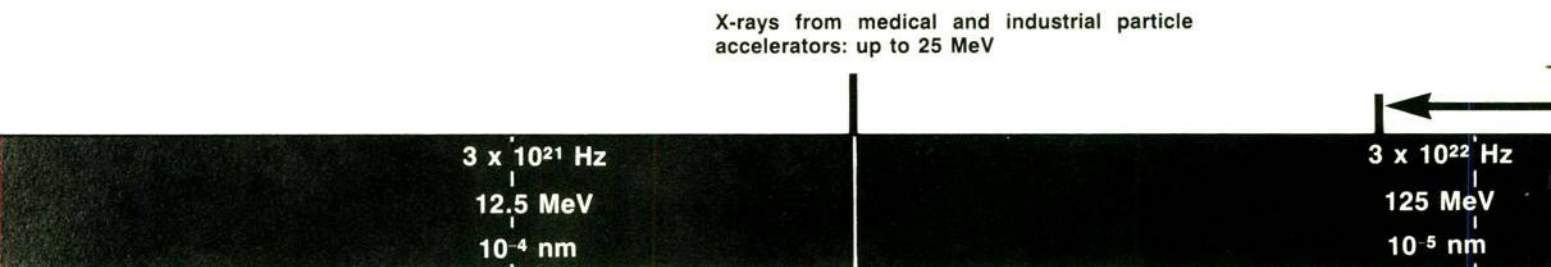
Europe’s Exosat and Japan’s Tenma are now aloft and conducting a variety of experiments. Within a decade, we may see the first craft carrying the new generation of more powerful X-ray imaging telescopes, among them NASA’s proposed Advanced X-ray Astrophysics Facility.

Mysteries of the Gamma Ray Universe

Our last remaining view of the electromagnetic cosmos lies in the ultimate short-wavelength region — the realm of gamma rays. And what a remarkable view it is! Through gamma ray eyes, we see a totally alien landscape: the inner sanctum of a quasar or active galaxy, the weird environs of a neutron star, and, at a finer level, the places where sub-atomic particles collide and shatter. Gamma rays behave more like bullets of energy than waves. In fact, astrophysicists normally describe them in terms of energy — measured in millions of electron-volts (MeV) — rather than wavelength. Our instruments have detected cosmic gamma rays with energies from 0.1 MeV (at a wavelength of about 0.011 nm, where we arbitrarily draw the boundary between X- and gamma radiation) to around one million MeV (a wavelength of about 1×10^{-9} nm). What mechanisms could contribute to such a vast range of emission?

There are also other difficulties in studying this strange and remote region of the spectrum. To detect gamma rays, we must use balloon-borne or satellite-mounted particle detectors. One type, called crystal scintillators, is used below about 20 MeV; the other type, known as spark chambers, is used to sense higher-energy gamma rays. These devices have a very poor sense of direction, however, and although highly sensitive, they are unable to do more than indicate the general area of sky in which

All regions of the electromagnetic spectrum overlap to some extent. It is possible, for example, to generate radiation of the same wavelength by "radio" as well as by "infrared" methods. Thus the spectral regions are somewhat arbitrary, largely reflecting differences in the dominant production mechanisms. Divisions in the electromagnetic spectrum represent differences of degree, not of kind.



a particular source lies. A second difficulty is that gamma ray sources are themselves incredibly weak. Even the strongest provide a detector with only about 100 gamma ray photons per second. And as if these problems weren't enough, sources of this energetic radiation are few and far between — only about 30 have been confirmed to date.

So what can we say about the origins of cosmic gamma rays? First, it's likely that they are non-thermal — that is, emitted by a process other than ordinary heat. To manufacture gamma rays thermally requires a temperature over 100 million degrees, and there are few likely objects that can meet this criterion.

Turning our attention to non-thermal mechanisms, we find a number of options. In regions where charged particles spiral along a strong magnetic field, gamma rays could arise from the synchrotron process. Throughout the universe, this is a common source of every kind of electromagnetic radiation. But other mechanisms are more peculiar to gamma rays. For example, if an atomic nucleus is "excited" — perhaps by collision with another particle — it will, almost immediately, emit a gamma ray of a certain characteristic energy in order to settle down into its lowest possible energy state. Similarly, a radioactive nucleus will eventually decay by emitting a "signature" gamma ray. In another type of process, an electron may collide with its antimatter counterpart, the positron. When the two meet, they completely annihilate one another and create two gamma ray photons, each with a characteristic energy of 0.511 MeV.

Balloon-borne detectors have done much of the observational work in the gamma-ray region. In fact, Marvin Leventhal of Bell Laboratories and Crawford MacCallum of Sandia National Laboratories used a balloon-borne instrument in November 1977, when they detected the 0.511 MeV positron-annihilation line coming from the galactic center. The presence of electron-positron annihilation lends support to the notion that the core of our Galaxy is undergoing unusual activity. And it fuels speculation about the nature of the central source: Is it an exotic stellar phenomenon? A massive black hole? Or, perhaps, a repository of antimatter? Future gamma ray observations may prove pivotal in resolving the issue.

Two satellites — SAS-2 and COS-B — figure prominently in our knowledge of the gamma-ray sky. The

former, launched in 1972, prematurely ended its mission when a power failure crippled the craft after just seven months. COS-B, a European craft launched in 1975, went on to study the gamma ray cosmos for almost seven years. The work of COS-B allowed astronomers to compile the first catalog of about 25 discrete gamma ray sources. The problem then became — and still remains — one of identifying these sources with objects known at other wavelengths, a difficulty enhanced by the poor positional accuracy of the detector.

The brightest beacons in the gamma ray sky are pulsars — young, rapidly-spinning neutron stars with enormously powerful magnetic fields. Two have been positively confirmed as gamma ray sources. Both are the remnant suns of recent supernovae and the youngest pulsars known — the pulsars within the Crab and Vela supernova remnants.

The gamma-ray pulses from the Crab and Vela sources occur at the same rate as the pulses in other parts of the spectrum; a common emission mechanism therefore seems likely. It probably involves the acceleration of charged particles, with subsequent release of synchrotron radiation near the magnetic poles of the pulsar, where the field is strongest. As the poles alternately pass across our line of sight, they beam toward us radiation — from radio waves to gamma rays — like a cosmic lighthouse. A pulsar's emissions decrease its rotational energy, so the pulsar spins more slowly as time goes on. As this happens, the lighthouse mechanism also winds down. Eventually, all that remains is a gently turning neutron star.

If the neutron star is solitary, this probably marks the end of its high-energy heyday. But if it has a close, normal stellar companion, its spectacular career may simply enter a new phase. By stealing material from its companion's atmosphere and whipping this gaseous loot into an accretion disk, the neutron star surrounds itself with a powerful source of X-rays. Such a system may also give rise to gamma rays. For instance, the X-ray binary Cygnus X-3 is a bright gamma ray source. Violent collisions between charged particles speeding out along the neutron star's magnetic field and atomic nuclei in the atmosphere of a normal companion star may account for Cygnus X-3's abundant gamma rays.

And then there are the enigmatic "gamma ray

Typical energy of primary cosmic rays — 100 MeV to 1000 MeV

Cosmic rays have been observed at energies up to 10^{11} GeV — about one meter to the right of this point!

3×10^{23} Hz
1.25 billion eV
 10^{-6} nm

bursters." In 1972, the United States launched the first of a series of Vela satellites designed to detect the electromagnetic radiation from foreign hydrogen bomb tests. As it turned out, they proved tailor-made for a far less parochial task. The Vela craft revealed sudden intense surges of high-energy radiation, each typically lasting a few seconds. But what was the origin of these bursts?

The spacecraft were strung out in a widely-spaced pattern around the Earth. By comparing the arrival time of a burst at each Vela detector and applying simple rules of triangulation, scientists determined the approximate area in the sky from which the burst came. Using this technique, Brad Schaefer of the Massachusetts Institute of Technology found a correlation between the position of a burster detected in November 1978 and that of a faint "flash" of light recorded on a 1920s photographic plate in the archive of Harvard College Observatory. He has since found several additional gamma-burst/optical flash correlations. What physical process could create these energetic events? There are several possibilities, but perhaps the most reasonable mechanism for generating a gamma-ray burst is an enormous thermonuclear blast on the surface of a neutron star. Here's the scenario: Hydrogen gas from a normal companion funnels onto a neutron star's surface along its powerful magnetic field. When enough matter accumulates, it violently explodes and suddenly releases vast amounts of energy, including the observed gamma rays. Since such an event would be recurrent and emit radiation across the spectrum, it could account for the flashes seen on old Harvard plates.

Other support comes from an observation, in March 1979, of a tremendously powerful gamma-ray burst. Lasting only 0.15 second, it released 100 times the energy of any previous burst on record. Most importantly, the gamma rays came from the direction of a supernova remnant in the Large Magellanic Cloud — suggestive evidence that the source was indeed a neutron star.

What of other gamma ray sources? There are several known extragalactic emitters, including one or two Seyfert galaxies, the nearby radio galaxy Centaurus A, and our old friend, quasar 3C 273. In each case, the observed gamma rays probably come from a region in which atomic nuclei collide with high-energy particles. One possible source is the accretion disk of a supermassive black hole.

In any event, gamma rays give us a probe with which we can investigate the powerhouse of an active galaxy or quasar.

So far, we've considered only discrete point sources of gamma rays, but there are also two known diffuse sources. One is an all-sky background of very low intensity and unknown origin. The other is confined to the plane of the Milky Way and is quite clearly a phenomenon in our own Galaxy. First spotted in 1967 by the third Orbiting Solar Observatory (OSO-3), the diffuse galactic emission is now thought due to cosmic ray bombardment of interstellar gas and dust.

Over the next decade or so, we can expect major advances in the entire field of gamma ray astronomy. The prospects are thrilling — equal to those of X-ray astronomy, say, 15 years ago. In the late 1980s, NASA plans to launch its Gamma Ray Observatory, a space platform featuring a large detector with a broader bandwidth than those flown on previous probes. Meanwhile, British and Italian workers are developing a balloon-borne telescope capable of giving a positional accuracy for gamma-ray sources of about five arc-minutes. Together with a proposed European Space Agency satellite fitted with similar instrumentation and the Soviet-French Gamma-1 probe, these missions could propel us into a new era of high-energy astrophysics.

Beyond the Photon

Electromagnetic radiation is vital to our understanding of the universe. It is easily our most important source of cosmic information, but it's not the only source. There are three other potential couriers, and even though all are vastly inferior to electromagnetic radiation as bearers of cosmic data, each offers the possibility of exploitation in the future. These "non-photonic" astronomies use cosmic rays, neutrinos, or gravitational waves. Of the three, cosmic ray astronomy is by far the best established.

Cosmic rays are high-speed particles with enormous energies that bombard the Earth from every direction in space. Roughly 90 percent of them are protons (hydrogen nuclei), the rest being helium nuclei (9 percent) and miscellaneous other particles, including heavy nuclei, electrons, and some anti-particles. When a "primary" cosmic ray hits an atom high in the Earth's atmosphere, it produces a shower of secondary cosmic rays. The latter,

3×10^{24} Hz

12.5 GeV

10^{-7} nm

The electromagnetic spectrum has no real beginning or end. The wavelengths depicted here span only the part of the spectrum known to be astronomically important and easily accessible to present detectors.

3×10^{25} Hz

125 GeV

10^{-8} nm

mostly mu-mesons, can be detected at our planet's surface using special instruments. By analyzing these secondary particles, we can determine the type, energy, and incident direction of the primary ray. We can also study the primary rays directly in space using satellites.

What we find is that most of the primary particles have energies between 100 and 1000 MeV. A few, though, have energies as high as 10^{14} MeV — equivalent to that of a tennis ball traveling at 100 kilometers an hour! Clearly, understanding the origin of these energetic particles is important. But it's also an extremely difficult task. Being electrically charged, cosmic rays are deflected by any magnetic field they happen to wander through. By the time they reach Earth, the particles can be coming from a totally different part of the sky than where they started out. We don't even know if cosmic rays are galactic or extragalactic in origin. The lower energy rays may arise from supernovae or their compact stellar remnants — both objects known to be capable of accelerating charged particles in intense magnetic fields. But what of the highest energy cosmic rays, particles packing the whallop of a fast-moving tennis ball?

An answer may emerge from the work of Marvin Marshak, Earl Peterson, and John Bartlett at the University of Minnesota. They placed a detector deep beneath the ground in a mine in Tower-Soudan State Park to try and detect the hypothesized decay of a proton; what it found was perhaps even more unusual. The device recorded what appear to be bursts of cosmic rays emanating from well-defined regions in the sky. One of these regions includes the constellation Cygnus where Cyg X-1, the famous black hole candidate, lies. Also close by is Cyg X-3, an object known to produce both X- and gamma rays. There may well be no connection between these objects and the cosmic ray bursts — the detector can give only a general idea of the source's position. Other researchers have shown that the cosmic ray electrons from at least one galaxy, NGC-3310 in Ursa Major, can result from local events, like supernovae, and global processes, such as the density waves that may create spiral arms (see "A New Source of Cosmic Rays?" *ASTRONOMY*, July 1984). Until we know more, astronomy using these strange celestial messengers will remain in its present embryonic state.

Much the same could be said of neutrino astronomy. Neutrinos are the "ghost" particles of the universe. They

travel at the speed of light, carry no charge, may have a tiny amount of mass (although this is controversial at the moment), and are extraordinarily difficult to detect. Oddly enough, the same property that makes them difficult to detect offers the greatest potential for neutrino astronomy — the particles' almost total reluctance to interact with matter.

Incredibly, most neutrinos arriving at the Earth penetrate not only the atmosphere — a feat in itself when we consider the fate of cosmic rays and most electromagnetic radiation — but the entire body of the planet! Zipping through as much as 13,000 kilometers of dense rock and metal in around 40 milliseconds, neutrinos resume their cosmic journey unaffected by the experience. Since neutrinos are created in high-energy regions where, for instance, atomic nuclei collide, they might provide us with a way of glimpsing the deep interior of objects like quasars, active galaxies, unusual stellar phenomena, and even normal stars such as the Sun. But we're still faced with the apparently awesome task of capturing these high-speed phantoms.

Scientists have built a number of neutrino detectors, and all have one remarkable feature in common — they are situated deep underground to eliminate otherwise overwhelming "noise" produced in the detector by particles less reluctant to undergo interactions with matter. A few kilometers of rock are sufficient to block out anything of cosmic origin (except neutrinos) and thus act as a perfect filter for this unique type of work.

Frederick Reines, one of the co-discoverers of the neutrino, was the first to set up a cosmic neutrino detector — or neutrino "telescope" — deep in a South African goldmine in the mid-1960s. But certainly the most famous (and tireless) effort to date has been that of Raymond Davis of the Brookhaven National Laboratory. Since 1968, Davis has spent much of his time tending the 610-ton tank of cleaning fluid (tetrachlorethylene) and peripheral equipment that comprise his solar neutrino detector. The Sun is the brightest source of photons and neutrinos in the sky, and Davis has set himself the task of determining the solar neutrino count to see if it's in line with what we'd expect based on current models of the Sun's interior. So far, the count is below expectations. In fact, it's too low to square with our present beliefs about the number and types of nuclear reactions taking place in the solar core. It's unclear, however, whether the discrepancy is due to

3×10^{26} Hz
 1250 GeV
 10^{-9} nm

A Breakdown of the Spectrum

Region	Wavelengths Absorbed in Atmosphere	Where Absorption Occurs (km above sea level)	Typical Detectors for Astronomy
Radio (longer than 10,000 m to 1000 μ m)	between 10 and 5,000 m reflected by ionosphere	300 km	radio receiver
Infrared (1000 μ m to 0.7 μ m)	100-700 μ m, 20-80 μ m, and 1-10 μ m	less than 10 km	charge-coupled devices (CCDs), some semi-conductors
Visible Light (700 to 400 nm)	none	transmitted to surface	CCD, television systems, photographic plates
Ultraviolet (400 to 10 nm)	300 to 10 nm	between 10 and 200 km	photographic plates, television systems
X-rays (10 to 0.01 nm)	all	between 80 and 150 km	television systems, proportional counters, scintillation detectors
Gamma rays (shorter than 0.01 nm)	all	between 50 and 80 km	scintillation detectors

incorrect stellar theory or to an incomplete understanding of the physics of neutrinos.

Present detectors are only capable of searching for low-energy neutrinos — the type produced in normal stars. However, there are proposals to build much larger and more sophisticated equipment to detect neutrinos of high energy, such as those produced during the collision of energetic cosmic ray protons with nuclei in the Earth's atmosphere. Among these is the proposal for DUMAND, a Deep Underwater Muon and Neutrino Detector sited on the ocean floor off the Hawaiian Islands, shielded by five kilometers of seawater. DUMAND would essentially be a greatly scaled-up version of some of today's detectors that work by sensing the tiny blue sparks of "Cerenkov" radiation that follow the collision of a neutrino with a nucleus in water. With its 2,500-plus light sensors located throughout 125 million tons of seawater, DUMAND would extend immensely the range of energies over which neutrinos could be detected. Neutrino astronomy, meanwhile, remains in the experimental stage and we must look to the end of the century for its first significant extra-solar results.

Finally, and perhaps most intriguing of all, there exists the possibility of observing the Universe by the medium of gravitational waves. The existence of these waves, and of "graviton" particles, isn't really questioned by most physicists. Any accelerating mass should, according to Einstein's Theory of General Relativity, produce "ripples" in space-time that spread radially outward from the source at the speed of light. General relativity has been vindicated by many experiments and is clearly the best available contemporary theory of gravity, so there's no reason to doubt this particular prediction. The real problem, even more severe than in the case of neutrinos, is detection. Gravitational waves are astonishingly weak. Even the largest masses, undergoing the most violent motions, produce only tiny ripples on the surface of space-time. And we are hard pressed, with the best available technologies, to devise equipment that will sense them.

Yet there have been many attempts to detect gravitational waves. One in particular, performed in 1969 by Joseph Weber of the University of Maryland, appeared to have succeeded. But other workers have since been unable to reproduce Weber's results, and we may have to await a new generation of more sensitive detection equipment before irrefutable direct evidence for

gravitational waves can be obtained. On the other hand, there is at least one piece of very good *indirect* evidence. This comes from observations of a remarkable binary star system, PSR 1913+6 in Aquila, in which one of the components is a radio pulsar.

PSR 1913+6 is an almost perfect gravitational laboratory. It contains two massive objects whirling around each other in a very tight orbit — it should thus be a "bright" source of gravitational waves. And since one of the objects effectively ticks like a precision clock, astrophysicists can determine the system's orbital period with extreme accuracy. The orbital period is decreasing at just about the rate expected, a prediction based on the anticipated energy loss from PSR 1913+6 due to the emission of gravitational radiation. At least three such binary pulsars are now known and, in the absence of direct detection, they may represent our best tools for studying gravitational waves for some time to come.

But the future of gravitational wave astronomy is bright. Unlike cosmic rays, whose directional data are scrambled by magnetic fields, we should be able to identify the sources of gravitational waves both within the Galaxy and beyond.

Today, astronomers see through polychromatic eyes that take in not just the traditional optical view, but the full cosmic panorama throughout the electromagnetic wavelengths and even beyond them. This has given us a more balanced perspective and a deeper understanding of the universe.

No longer does space seem calm and orderly. We've become aware of its high-energy phenomena, its rapidly-varying phenomena, its condensed objects — and an enormous variety of cosmic species. We've witnessed the birth and rapid ascendancy of radio astronomy in the 1950s, the discovery of quasars and pulsars in the 1960s, and the brilliant successes of space-borne X-ray astronomy in the 1970s. Now, we stand on the threshold of new breakthroughs and of new spectral visions that will come from the orbiting astrophysical laboratories of the 1990s.

David Darling, who received his Ph.D. in astronomy from the University of Manchester, England, is a computer consultant and freelance science writer. His last article for ASTRONOMY was "Spectral Visions, Part 1: The Long Wavelengths," in the August 1984 issue.

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ASTROPHOTO OF THE MONTH



The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 min., C-14 at f/6.

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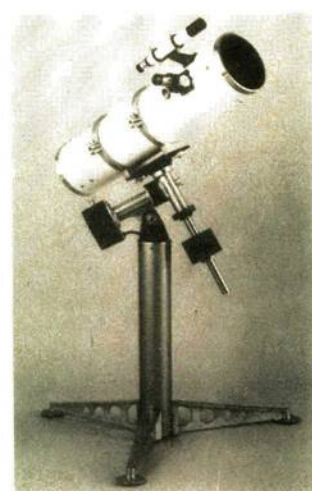
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ASTRONOMY Forum

An Interview with Ken Fulton — the “Light-Hearted Astronomer”

Q: Mr. Fulton, when did the astronomy bug first bite you?

KF: Probably before I was potty-trained. I really can't remember a time when the clear night sky did not fill me with wonder. I really got into astronomy in my early teens, when my parents gave me a 4-inch reflector for Christmas.

Q: Was it one of those cheap department store models you always warn against?

KF: No. I was extremely fortunate on that count. I had been reading *Sky & Telescope* magazine faithfully at the public library for about a year. (ASTRONOMY wasn't around then.) Well, I had memorized the ads, so I knew exactly what scope I wanted Santa to bring me — a Questar! But I also knew Santa couldn't afford to bring me that beauty, so I opted for an inexpensive 4-inch Criterion Newtonian — a scope that turned out to have excellent optics. I still use it. It still delivers. I'm gonna take it with me when I die. God said I could. I'm told the seeing is always “10” in heaven.

Q: I imagine you felt like you were already in heaven when you received that first telescope, right?

KF: For a while, yes. But then, after the newness wore off, I felt like I was in hell. You see, I had never looked through an astronomical telescope before, unless you count my \$2.49 Roy Rogers & Dale Evans Double-R-Bar Binoculars. I had all these ridiculous preconceived notions about what I would be able to see and about how easy this amateur astronomy thing was going to be. I had the classic just-plug-in-the-eyepiece-and-see-everything type of attitude. Well, I found out real fast that amateur astronomy doesn't work that way. I had expected my

little telescope to run with me before I had even learned how to *crawl*. I just put it up in the closet and didn't touch it for months. I thought amateur astronomy was for very dumb birds.

Q: What changed your mind?

KF: The universe. She kept calling out to me — I guess “seducing me with her magnificent presence” would be a better way to describe it.

Q: Evidently you kissed and made up. How was the reconciliation?

KF: Painful. I wish I could say that it

*When you decide to
attempt amateur
astronomy, you
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determination,
sensitivity, fortitude,
and worthiness to
survive the trip...*

was like that classic scene in the movies where you see the two lovers running back to each other while the music swells in the background, but the universe will not run to anyone — Carl Sagan included. I more or less crawled back. Even so, I don't think she acknowledged my existence for two years.

Q: Explain.

KF: Even then, I kept an observing log. Reading the observations of those two years is like reading a Stephen King horror story. I worked like a mule

to survive as an amateur and made every mistake in the book.

Q: Why didn't you just give it all up?

KF: Down deep in my gut, I knew I was *worthy*. In a strange and mystical way, I knew the universe wanted me to appreciate her beauty, so I made up my mind to let nothing — and I mean *nothing* — keep me from being an amateur astronomer: not bad seeing, stupid blunders, faulty optics, disreputable dealers, exaggerated ad claims, slow deliveries, bad exposures, eye and neck strain, or ignorance on my part. There were nights when I had such ungodly troubles observing that I felt I was in the Twilight Zone. It was a time of almost total frustration. The whole business made my stomach burn and bubble. There were nights when I literally shouted “I'm not gonna give up!” to the night sky, and then gave up. There were times when I developed roll after roll of astrophotos only to stomp the negatives to you-know-where. Times when I slapped my telescope out of alignment. Times when I kicked it out of alignment. And there was one time when I threw a perfectly good eyepiece — only God knows where — deep into a thicket.

Q: What made you do that?

KF: I couldn't resolve as many cloud bands on Jupiter as I wanted to. According to my log, the seeing that night was horrible — but I blamed the poor eyepiece. I never did find it.

Q: And this sort of misery went on for two years?

KF: Yes. And it still goes on to a lesser degree. Sometimes, I still get those feelings. I don't throw eyepieces anymore, but I still stomp negatives from time to time and kick other things. Never my telescopes, though. Usually trees. They don't seem to mind.

Q: Does the universe promise anything?

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Light-Hearted
Astronomer**

by Ken Fulton

**A Survival Manual for
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"Fulton has done astronomy an invaluable service. I think a lunar crater should be named after him."

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"Look . . . my husband eats, drinks, and sleeps astronomy while I work my fingers to the bone keeping our household afloat. He loves astronomy so much that he'll probably spend what money he makes off this book to buy another eyepiece or something, even though I badly need a new mop. And you want me to write something praiseworthy about this book? You've got to be kidding!"

— *Doris Fulton, wife of the author*

"I really can't make heads nor tails of this book. It's funny, so it can't be an astronomy book. It's a survival manual, so it has to be dead serious. And it can't be fiction, because there are no obligatory sex scenes in it. I dunno. . . I think I'll pass on this one."

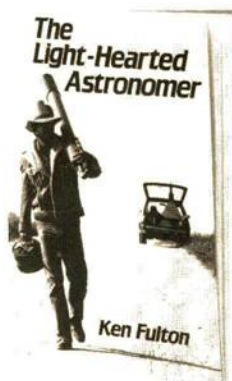
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handy order form bound into this magazine.

KF: Yes. A chance to embrace her. An opportunity — nothing more — to travel the stars. An open door . . .

Q: All this sounds like a big gamble.

KF: It is a gamble. When you decide to attempt amateur astronomy, you gamble that you have the courage, determination, sensitivity, fortitude, and worthiness to survive the trip into the jungle.

Q: What about intelligence?

KF: Intelligence is not a prerequisite. Certainly it is a very handy optional accessory, but not mandatory. I'm evidence of that. If I can become a darned good amateur astronomer — and I am — then anyone can.

Q: Could you describe your redeeming qualities as an amateur?

KF: Okay. I'm doggedly persistent. I don't give up . . . for long. That's a prerequisite for being a successful amateur astronomer — or a writer. I have enough slips rejecting my writing to wallpaper my bedroom. If the universe gave out similar slips, I'd have enough to wallpaper the Smithsonian. I'm not highly intelligent, but I'm blessed with a good deal of common sense. I'm sensitive. I notice things that many people don't notice, like the texture of a sheet of typewriter paper, for instance. Every page has a different complexion, and I find that fascinating. I'm sensitive to subtle nuances in just about everything, so I see things others don't see. My powers of observation are acute. Also, I have a sense of wonder — especially when it comes to something infinite like the universe. And too, I have this tremendous thirst for beauty.

Q: Do you have a thirst for knowledge?

*I consider the
universe a magician.
I get a real kick
out of seeing her
perform her magic.*

KF: If you mean do I long to discover something undiscovered about the universe, the answer is no. I don't approach astronomy as a scientist. I'm an admiring observer. I consider the universe a magician. I get a real kick out of seeing her perform her magic, but I don't necessarily wish to know how she does her tricks. For some reason, that takes away some of the magic for me.

Q: I can hear scientists gasping right now.

KF: There's no reason they should. I

do my own thing and they do theirs. I admire scientists, especially astronomers. I am constantly amazed at what they can figure out about what is up there. But when it all comes clean, I'm an admirer, nothing more. That keeps me plenty busy.

Q: I find it difficult to believe that you are not interested in the scientific investigation inherent in astronomy.

KF: I didn't say I wasn't interested. It's just that finding answers to astronomical problems is not the reason I observe. I'm first and foremost a sightseer — a tourist, if you please. To be a scientist and get any useful work done at all, you have to focus on one tiny aspect of astronomy and dwell there. You can only work with one piece of the puzzle, not the whole puzzle. I don't want to be tied down.

Q: And yet you mention in your book that you specialize in lunar observing.

KF: True. I observe Luna a great deal because there is a lot of accessible detail to appreciate there. I mean, you've got to admit the Moon has a lot going for it. It's got a marvelous and visible complexion, and it's a breeze to locate. I can study it for hours on end, but I don't dwell on it to the extent that I neglect what else is up there. I'm hooked on nebulae, clusters, and the planets Jupiter and Saturn. Mars, on the other hand, doesn't do much for me. Neither does Venus. In more than twenty years of observing, I've never enjoyed a really satisfying view of either planet. I like sights that get my adrenalin flowing.

Q: You've just alienated a bunch of Mars and Venus fans.

KF: I hope not. I didn't mean to. I've got this close friend who couldn't care less about observing the Moon. He's hooked on searching for extragalactic supernovae. We get along just fine. The "pie" is big enough for everyone to have their fill, and more. That's one of the neat things about astronomy.

Q: A few moments ago, you mentioned that you considered yourself a darned good amateur astronomer. That sounds a bit arrogant.

KF: Well, I don't see how you could seriously pursue astronomy for over twenty years and *not* be pretty darned good at it. The very fact that I have survived all those years in the jungle attests to something. I *am* good. That's no arrogant brag, just fact. And I'm not the Lone Ranger. We survivors are legion.

Q: *The Light-Hearted Astronomer* is not your run-of-the-mill astronomy book. For one thing, it's written in an almost conversational tone.

KF: I write that way because what I have to say about amateur astronomy is up-close and personal. The main reason I wrote the book was to help amateur astronomers survive the

jungle. I survived with little outside help, and I've got the scars and horrible memories to prove it — but I don't want others to go through what I did. The book is intensely personal. It's *me*. When someone reads it, I want them to feel as though I'm right there guiding them through the jungle, holding their hand, protecting them from the toothy beasts, and caring about them. That's why it's not a science book. It's a *caring* book.

Q: It also doesn't look like your normal astronomy book. There are no formulae, no star charts, no science, and none of the usual astrophotos.

*Most astronomy
books speak directly
to the brain; mine
speaks to the heart.*

KF: Correct. Why re-heat yesterday's stew? You can find all that in other books. Most astronomy books speak directly to the brain; mine speaks to the heart. And as far as astrophotos are concerned, you can find excellent color and black-and-white pics in almost any text on astronomy. They're beautiful, but not a single one ever taken does its subject true justice. And they have a real potential for doing harm to a beginning amateur because they can give a tenderfoot an erroneous notion of what they will see in the eyepiece of their first telescope.

Q: How can that be?

KF: They buy their first telescope and expect to see color in the Orion nebula, or forty-eleven cloud bands on Jupiter, or a volcano on Mars, or the Horsehead — things like that. And when they find they can't see these things, they suffer a gut-wrenching disappointment that, in too many cases, causes them to give up on astronomy altogether.

Q: Now you've alienated astrophotographers.

KF: No I haven't. Astrophotographers are thick-skinned. They have to be, or they wouldn't last two minutes in the jungle. Now don't get me wrong. Astrophotos are neat. I've taken thousands of them. It's just that they fail to convey the beautiful subtleness of what's up there. They give a false impression of what you will see in the eyepiece.

Q: Do you think professional astronomers will enjoy the book?

KF: If they've gone through the usual trials and tribulations, I think so. If anything, they should appreciate the book's sincerity.



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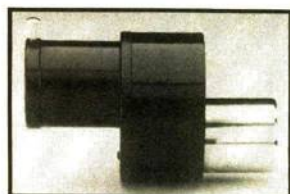
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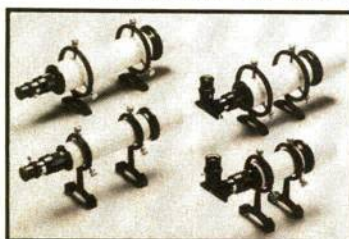
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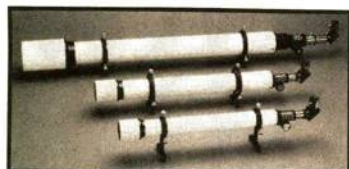
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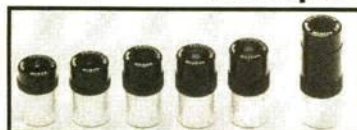
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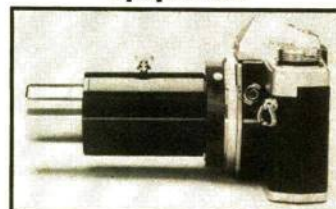
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Q: Do you think the book reviewers will be kind to you?

KF: I certainly pray they don't draw-and-quarter me. If they give it a chance, I think the book will serve its purpose and do some real good. All vanity aside, I think *The Light-Hearted Astronomer* has filled a hole in the literary landscape of astronomy.

Q: Some who have read your articles have suggested that you are too lenient with telescope and accessory dealers concerning delivery times or the failure to adhere to dates of promised delivery. Did you get tougher in the book?

KF: No, because I don't think I was too lenient at all. I happen to think we amateurs have it pretty darned good when it comes to places where we can purchase astronomical hardware. And by and large, the dealers are topnotch. The problems normally stem from supply and demand, not lies and larceny. Granted, some dealers are not as up-front with their customers as they really should be — but I still feel that the bottom line is whether or not those dealers eventually deliver a quality piece of merchandise.

Q: At the expense of their customer's sanity?

KF: Patience is also a prerequisite to becoming an amateur astronomer. Amateur astronomers all over the globe are force-feeding dealers with orders. "I Want It Now!" fever is rampant, and is a very real and painful thorn in the flesh for dealers. Everybody admits that quality cannot be rushed, but that doesn't seem to stop everybody from rushing it.

Q: It still sounds like you're on the dealer's side.

KF: I guess I'm just glad they're there. Can you imagine what it would be like if all of them just vanished? The dealers aren't perfect, but they exist, thank God.

Q: Will you admit that a number of highly successful dealers often fail to live up to their promises when it comes to delivery times?

KF: Yes, but I happen to think that's a little sin, and we all sin a little, don't we?

Q: Some would argue that it's not a little sin if you're the one being sinned against.

KF: It doesn't *seem* to be a little sin, I know. I've been stung several times, and one time it did border on larceny. But I didn't let it turn me bitter as many people do. I didn't let those times make me paranoid about dealers. I kept on truckin' until I saw both sides of the coin.

Q: The book devotes an entire chapter to dealers' advertising strategy. You indicate that there are problems in this area, but still you do not lay the full blame on the dealers for their overheated ad hype. Why?

***We, the customers,
set the tone of
advertising, because
we respond or do not
respond to it.***

KF: Because I honestly don't think the dealers are to blame. We, the customers, set the tone of advertising, because we respond or do not respond to it. Down the line, we have never encouraged complete honesty in any form of advertising. We want every single 8-inch telescope available to be the best in its price range, and we expect the ads to hawk the scope as such. If they don't, we don't respond with orders. Amateurs are responding to ads now more than ever before, and the ads are more hyped-up than ever before. The strategy *works*. It's a vicious circle. The more overblown and exaggerated the ad hype, the more we respond. I don't blame the dealers. I blame the customers for not taking everything that's said in the ads with a grain of salt and not using their common sense.

Q: Wow! Now you've alienated everyone who has ever been seduced by ad hype.

KF: I've been seduced lots of times. I've been fooled. I've been hurt. But that's life in the jungle. It comes with the territory. If you play football, you've gotta expect to get bruised. No pain, no gain.

Q: That sounds a bit harsh.

KF: Amateur astronomy is not for the weak of spirit. I never said it was easy. You've got to be tough and keep your sense of humor.

Q: A sense of humor is important?

***Never take yourself
too seriously.
Amateur astronomy
should be fun.***

KF: Yes, very much so. I would even say it's a prerequisite. Never take yourself too seriously. Amateur astronomy should be fun. You must learn to laugh at times you feel like crying.

Q: Have you learned that?

KF: Pretty well. Still, there are times . . .

Q: Are you completely satisfied with your book?

KF: I think the book accomplishes one thing — helping the amateur enjoy the ups of amateur astronomy and survive the downs. I hope it conveys my enthusiasm for the hobby and infects the reader with my love for the universe. And I pray that it does some little something to help assure my children of clear skies.

Q: How so?

KF: Thanks to air and light pollution, it's getting more and more difficult for light from celestial objects to tunnel through all the garbage. Non-astronomers might be concerned about such pollution, but they are not as concerned as they should be because, for them, it doesn't strike close to home. Astronomers can see that our window to the stars is getting filthy. And that, my friend, hits home, where we're concerned. We are very aware of what is happening. I want more and more people to fall head-over-heels in love with astronomy so they will have something personal at stake — the visible universe. Maybe then, they will fight like hell to keep it visible. The more soldiers there are to fight, the better chance we'll have to win. If something isn't done fast, there will come a day when even Questars will gather dust on the shelf because there is nothing to see. Thinking about it makes me ill.

Q: On a lighter note, do you think this book is your big chance to get rich?

KF: No. I only hope to make enough from its sales to pay for a custom-made state-of-the-art 12-inch refractor tucked under a dome.

Q: And how much will that take?

KF: Around half a *billion* dollars, shipping not included. Actually, I just wanted to get in the word "billion" at least once. After all, it paid off for you-know-who.

Q: I understand you've already decided what you would like inscribed on your tombstone.

KF: Yes. Here lies a remarkable 4-inch reflector and Ken Fulton, a darned good amateur astronomer who died while observing at the age of 634. He is observing still.

Q: I certainly hope you live that long.

KF: The feeling is mutual.

— Ken Fulton
Temple, Texas

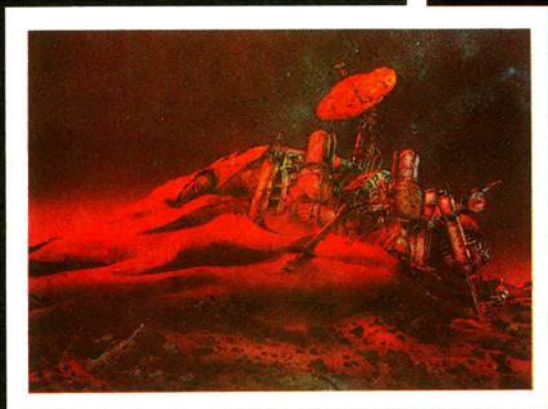
Ken Fulton's two loves, astronomy and writing, have been uniquely joined in *The Light-Hearted Astronomer*, a survival manual for amateur astronomers, published this June. He is now in the process of finishing his first science fiction novel and collaborating on another. When not busy promoting his new book, Ken likes to get out under the stars.

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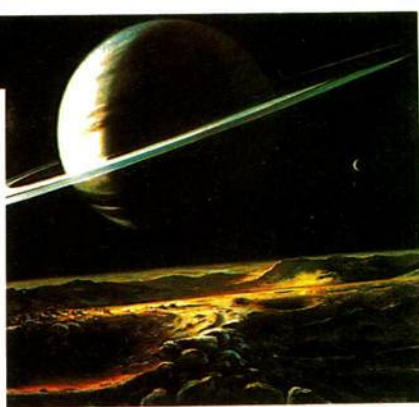
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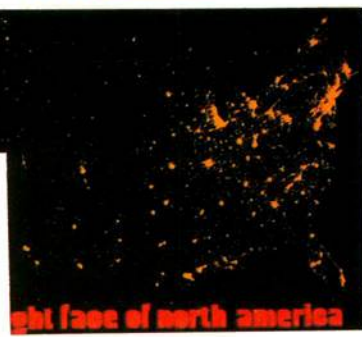
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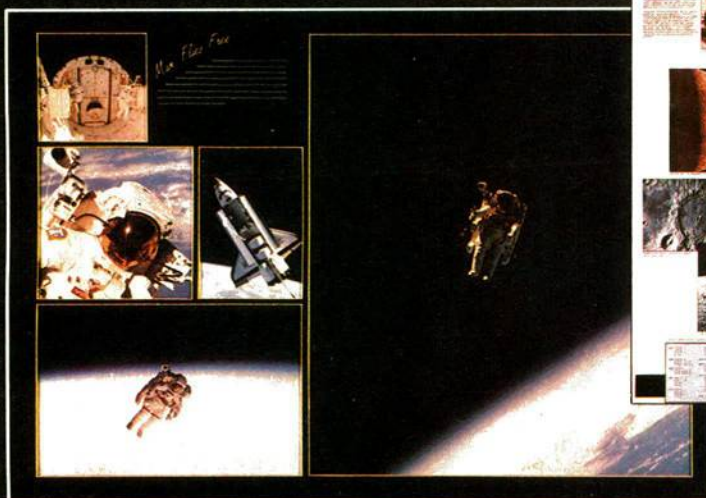
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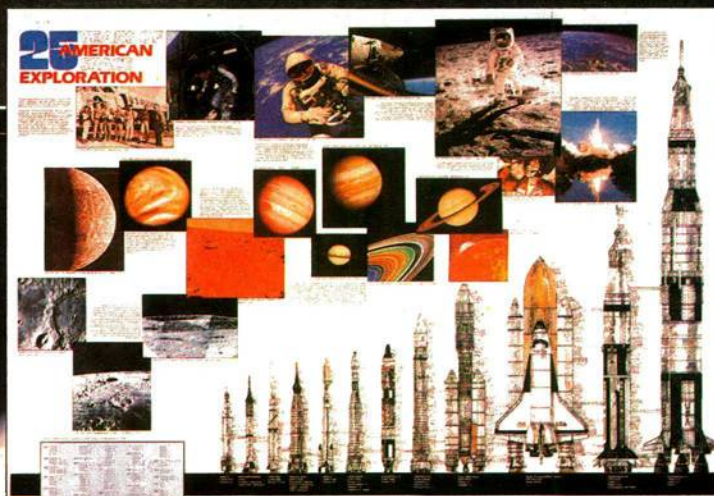
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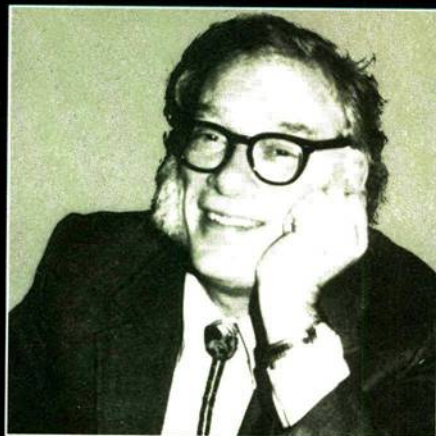
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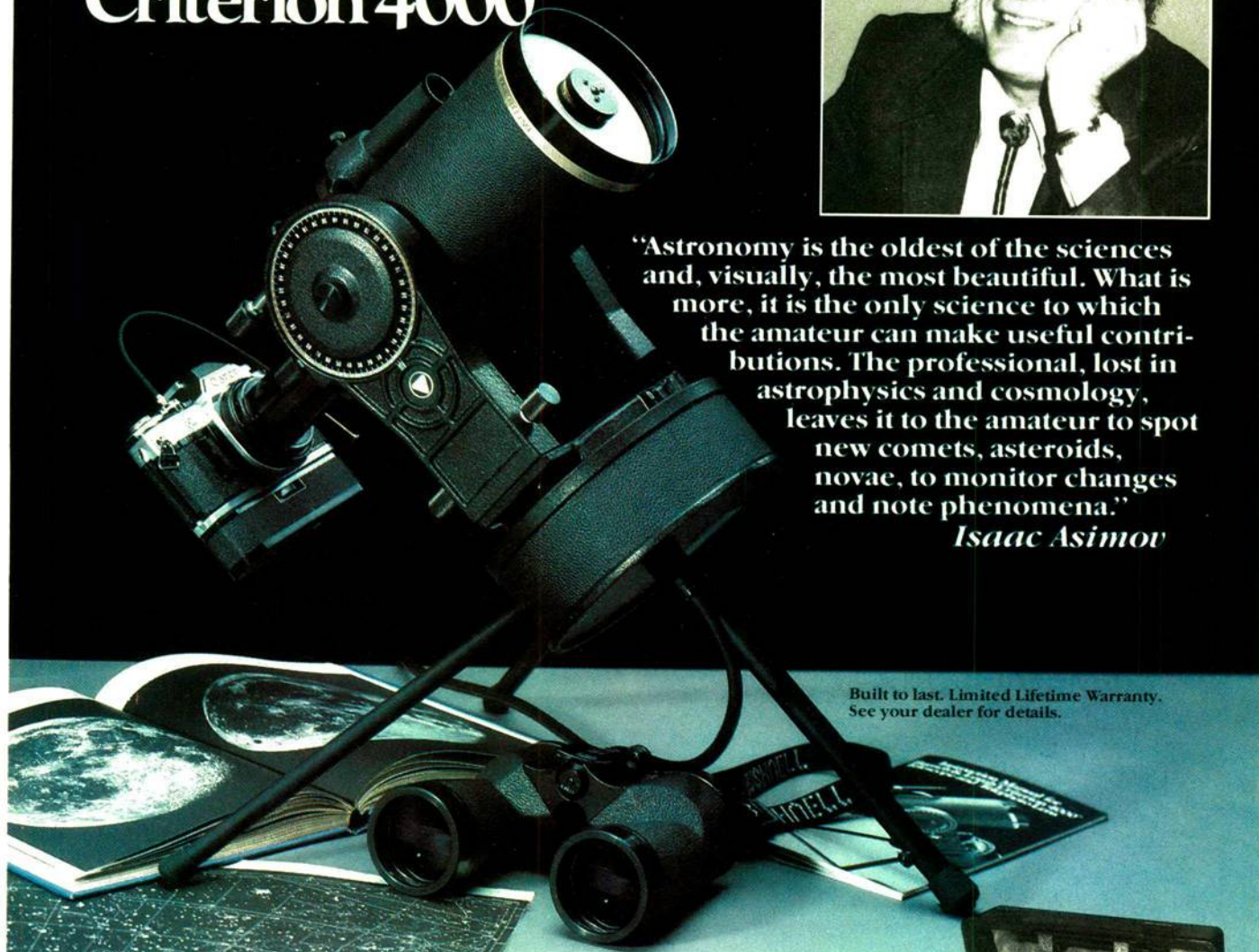
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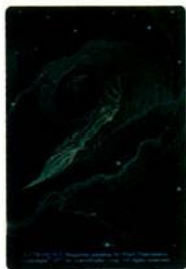
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ASTRONOMY

In Focus

Those & *%\$#@ Aliens

Sir / Richard Parlour (Forum, July) raises an important issue by questioning the assumed benevolence of aliens. To support his statements he quotes Anna Hollin as saying we know nothing about them. I agree. He then asserts as fact his belief that aliens must be 10 million years ahead of us in their development. I question this.

To understand our attempts at contact, aliens would have to be technologically as advanced as we are. However, his 10 million year figure is as unlikely as the two species being exactly the same age. Implicit in his hypothesis is that all societies and races follow the same evolutionary course in the same time and in the same directions.

Also, drawing from our experience of human malevolence, Mr. Parlour raises the specter of an alien Hitler. It seems to me that pure malevolence dies of its own excesses, and conquerors either rule somewhat benevolently or eventually lose. Further, the logistics of conquest across light-years of space would be a major deterrent. My own belief is that the technological base necessary to travel in space cannot be developed in the environment of hatred and malevolence.

Since there is a risk, we should exercise care, but we must not stop trying. Our very nature is to be curious and exploring. There is only one genuine frontier left, and it is overhead. Remove that frontier and you shut off mankind from its ultimate hopes and dreams.

William S. Keezer
Plainfield, IN

Sir / Richard Parlour's reasoning is quite valid concerning why we should not be so quick in our attempts to contact aliens. However, it's too late — unless he advocates a total ban on

commercial broadcasting, national defense radar, 60 Hz power transmission, and so on.

As many have pointed out before, any intelligence within 65 light-years of Earth could know that we are here. And any intelligent beings within 35 light-years know what we look like. Let's just hope they have a sense of humor to appreciate Ernie Kovacs!

Grant Martin
Cincinnati, OH

Sir / Richard Parlour would do well to ponder why astronomers and other scientists so universally assume that advanced alien civilizations will prove to be benign. It is not surprising that his fearful concerns about "extraterrestrial devils" are met by the scientific community with "speechless, wide-eyed bewilderment."

Mr. Parlour is correct that this is an assumption, but I think it is a sound and safe one. Lack of proof does not mean *ipso facto* that "to attempt communication is to invite a disaster as overwhelming as a thermonuclear holocaust." Let us confidently attempt to engage in conversation whatever aliens may be listening.

John Sellen
Minneapolis, MN

Sir / Why, Mr. Parlour, do you insist that they have to be evil? "Technological excellence does not imply moral excellence" is quite true, but it does not follow that technological excellence is evil, either.

Cindy Cline
Fairfield, CA

Sir / Richard Parlour's article gets my vote for the Ostrich Prize of 1984. If human beings had evolved with the attitude of "Let's not do it because it might lead to disaster," we would still

be skulking in the backs of caves, and some form of insect would probably be the dominant lifeform on Earth.

Second, any race more than a few million years older than us would scarcely be able to recognize our attempts at communication or attribute any degree of intelligence to the senders. They wouldn't ignore us — they simply wouldn't notice. What we *should* fear, if anything, is a race perhaps 10,000 to 15,000 years ahead of us which is in the process of aggressive expansion. If they happened to like the looks of our planet and decided to move in, we'd have a nasty war on our hands, I grant you, but it would hardly be one-sided. (To see some of what I mean, read Larry Niven's series beginning with *World of Ptavvs*.)

Third, I object to any very expensive attempts to send communications to outer space, because they might divert funds from what I consider the better way — namely, an all-sky radio and microwave survey to see if some of the electromagnetic energy pouring in contains intelligent messages.

Finally, quite aside from deliberate attempts to communicate, we have *already* been communicating, inadvertently, for a good 50 years or so. Television and microwave broadcasts are not reflected by the ionosphere, so all such messages are out there, traveling away at light-speed. Alpha Centauri is about to learn of Ronald Reagan's election, and everybody this side of Sirius knows what happened to Richard Nixon. (Pause and consider what some alien might make of us based on "The Howdy Doody Show" or "I Love Lucy"!)

Hugh W. Thompson
Flushing, NY

Sir / "Undesirable Aliens" was well thought out and addresses issues so weighty that even the most myopic

individual would have to take notice. Surely, within the hallowed walls of DoD or the hermetically sealed confines of the "think tanks" Mr. Parlour's propositions have been weighed and considered. Or did those who gave birth to Project Ozma and the like reason that the probabilities of a contact were remote to begin with?

Come on, you guys up there at MIT, RAND, etc., etc., with your white socks and button-down collars! We don't mind you playing with our genes. You can even "Step on My Blue Suede Shoes." But, I mean, you know, this searching around the cosmos for intelligent life is *totally* far out. Slow down, you're moving too fast. You've got to make the morning last.

C. Michael Bradshaw
Crofton, MD

Astronomical Networks

Sir / Regarding the astronomical networks proposed by Mr. Russell Chabot (In Focus, April 1984):

There is a comet watch computer bulletin board system (CBBS) at (305) 268-8576 which is a 300/1200 baud system. NASA has a CBBS at (301) 344-9156.

On Friday mornings at 0400 UTC on 6185 kHz, Radio Earth has a one-hour show that is of particular interest to amateur astronomers.

At 0500 UTC every night, there is an Amateur Radio Net called the Astro-Net that meets on 3.885 MHz on the lower sideband.

Amsat has a CBBS at (512) 852-8194 for those interested in Amateur Radio Satellites.

Jay D. Miller, III
Albuquerque, NM

Spotting Pluto

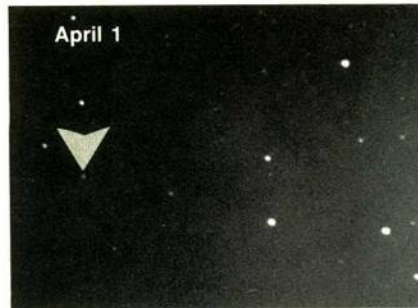
Sir / I was happy to see David J. Eicher's article "How to Hunt Down Pluto" in the April issue. Ever since I became interested in astronomy some seven years ago, I've been a deep-sky observer; but this article and the finder chart prompted me to try to find the elusive little planet. On May 17th, a few minutes before moonrise, I went out and quickly identified the correct field, and soon had a suspect in view in my 10-inch Newtonian at 186x. I made a sketch. On the following night, I went out again and — sure enough — the little speck of light had moved! Eicher mentioned that the people who have seen Pluto are members of a "very select group." Using the excellent finder chart, the very select group should actually be a healthy portion of backyard astronomers!

Steve C. Schwarz
Pinckneyville, IL



Pluto on Film

Sir / After reading the article on hunting for Pluto, I decided that I just had to try to find the outermost planet. The problem is that I live in a relatively light-polluted area of suburban New York City, where my 8-inch f/10 SCT cannot show me stars fainter than magnitude 12. Realizing that Pluto hovers around 14th magnitude, I decided to try to photograph the planet. The results are enclosed: I used hypersensitized TP 2415 and a 20-minute exposure on March 27 and April 1, and recorded



the motion of the outermost member of our solar system.

Frank J. Melillo
Valley Stream, NY

Ooops!

You can all stop writing in to ask for your free star map — it's the Star Dome in the center of Eye on the Sky. We were conducting a test promotion with our newstand copies, and failed to instruct our printer to remove the headline from the subscribers' July and August issues. Sorry!

Behind the Scenes | Specialized Reading

Astronomy is a broad field, and ASTRONOMY magazine attempts to cover it all for a wide readership of astronomers, amateur astronomers, and astronomy enthusiasts. So, although there are 60 editorial pages between our covers every month, there simply isn't enough space to cover all the things we'd like to cover. That's why, in addition to ASTRONOMY, we publish two specialty magazines, *Telescope Making* and *Deep Sky*.

The idea for *Telescope Making* came to me a little over six years ago. I've always been interested in building telescopes, because, quite frankly, I didn't have the money to buy a telescope. I knew, as ASTRONOMY's Editor, that some of our readers wanted to read more about making telescopes, but keeping that group happy would distress other readers. Then I had the good fortune to meet Robert Cox, the best-known telescope maker in the US; between us we hatched plans for an independent magazine all about telescopes. AstroMedia was willing to back us; the rest, as they say, is history. Our current issue, TM#23, features optimizing Newtonians, the new observatory at La Palma, and a 20-page report, with pictures, on new ideas from the Riverside Telescope Makers Conference and the Texas Star Party. See what I mean by "not enough space"?

Deep Sky is the brainchild of David Eicher, a young amateur astronomer from Ohio who joined ASTRONOMY's staff a little under two years ago. He had been publishing DS himself, but the effort was too much for him to continue alone. We gave *Deep Sky* financial backing, and Dave, with the help of ASTRONOMY's Robert Burnham, has done the rest. The current issue, *Deep Sky 7*, features a detailed round-up of deep-sky objects in Cygnus (and I do mean detailed — over 70 main objects plus 20 little-known clusters and nebulae that even the RNGC overlooked), a complete list of the 19 known globular clusters in Ophiuchus, and Part II of a special feature on those hard-to-find low-surface-brightness objects that you've probably never even heard of before. If you've gotten tired of M-31 and the Dumbbell Nebula, DS provides plenty of observing challenge.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

P.S. — TM is \$12 for four issues, \$21 for eight issues; DS is \$10 for four issues, \$18.50 for eight issues. Foreign orders are slightly higher. For complete information, see ASTRONOMY, August, page 25.

Learn the Fall Stars

by
Earle F. Dodds

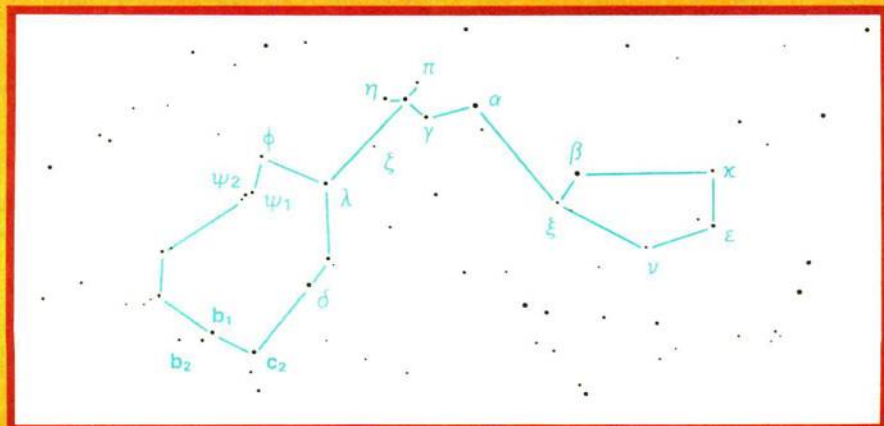
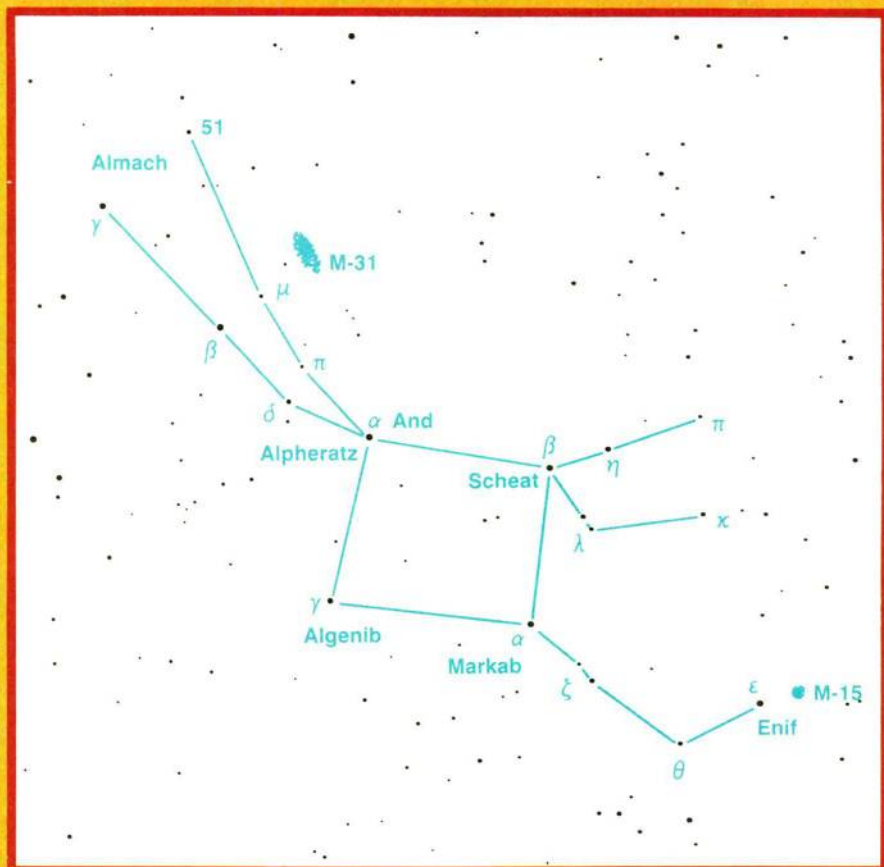
In our series on the sky's constellations, we've looked at the stars of winter, spring, and summer. Now that the cool, crisp, and often haze-free nights of autumn are here, it is time to gaze upward at their groupings; here you'll find many curious constellations and binocular sights.

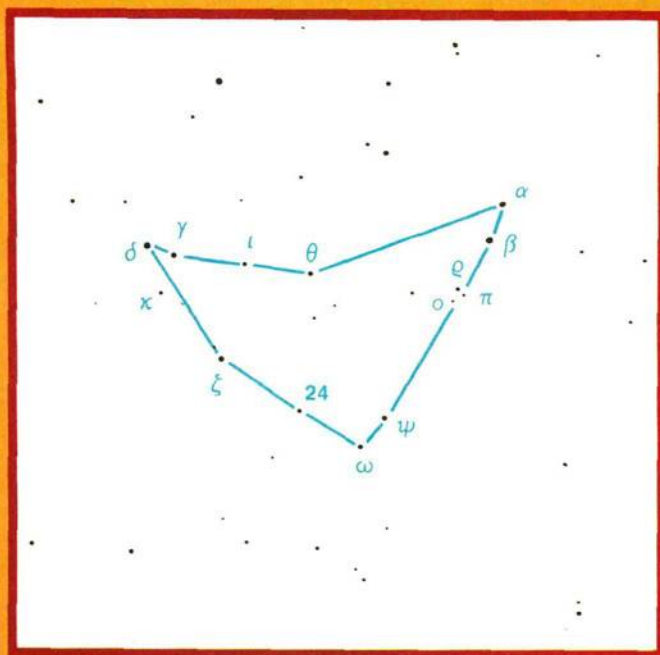
On September 1, at 10:00 p.m., the summer Milky Way looms large toward the southwest — the glittery star clouds of Sagittarius, Scutum, and Scorpius, which indicate the direction of the center of the Galaxy. Though these rich areas of sky will soon be gone until next summer, your binoculars will afford one last glimpse of the heart of the Galaxy. Antares, the brilliant orange "alpha star" of Scorpius, sets by the time the sky is good and dark, but the tail of Scorpius remains visible. The large open star clusters at the Scorpion's tail, M-6 and M-7, appear as fuzzy patches to the naked eye and resolve into multitudes of stars in binoculars. The dimly glowing gaseous nebulae M-8 and M-20, found northwest of the teapot formed by the stars of Sagittarius, look like small hazy spots to unaided eyes; but binoculars reveal their nebular nature, showing faint but distinct clouds of greenish hazy light. An object for owners of larger binoculars is the globular star cluster M-22, found on the northeastern side of the Teapot.

Following the Milky Way northward,

The most commanding sight of the fall sky is the Great Square of Pegasus, which contains four stars of magnitudes 2.5 and 3. Alpheratz, the star in the upper left hand corner, belongs to the connected group of stars known as Andromeda. M-31 is a nearby spiral galaxy; M-15, a globular cluster, is visible in binoculars.

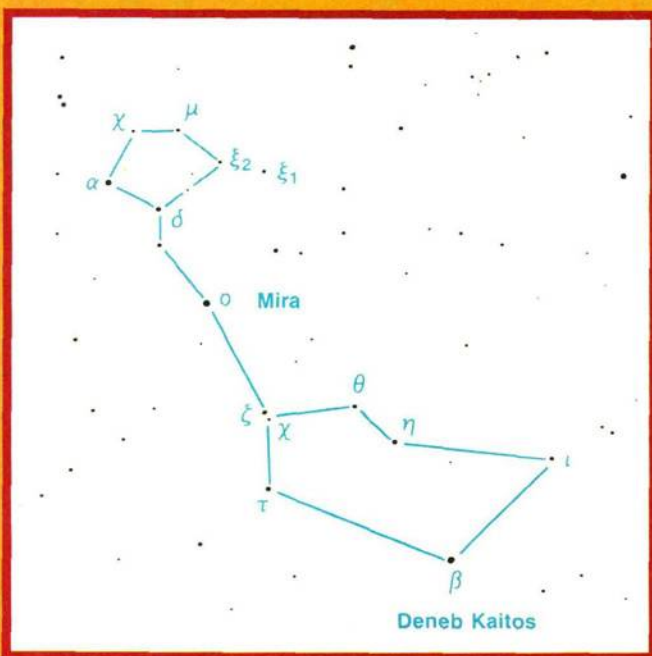
Aquarius the Water Bearer is an irregularly shaped group of dim stars. The brightest is Alpha Aquarii, sometimes known as Sadalmelik, which is a yellowish, Sun-like star shining at magnitude 2.9. Beta Aquarii, Sadalsud, is a 3.1 magnitude yellowish supergiant.





Capricornus is known as the Sea Goat; its brightest star, Alpha Capricorni, is called Giedi — which means goat! Giedi is a wide double star, but its fourth magnitude components are separated in space by 1,000 light-years — they are paired only by coincidental alignment.

Cetus the Whale holds an unusual collection of stars: Alpha, or Menkar — meaning “nose of the monster” — is a magnitude 2.5 reddish star lying only 130 light-years away. Omicron, or Mira, is the most famous of the long-period variable stars, changing from magnitude 2.0 to 10.1 in 332 days.



we find the diminutive constellation Scutum the Shield now well placed for viewing. Roughly centered on this tiny group of stars is a bright patch of Milky Way called the Scutum Starcloud — the light from hundreds of thousands of individual stars. Binocular owners can spot a very rich open cluster in Scutum — M-11, the Wild Duck Cluster. Just north of Scutum is Aquila the Eagle, whose brightest star, called Altair, is a bluish-white beacon of magnitude 0.8. Altair is one of three stars composing the Summer Triangle; the other two are Deneb (Alpha [α] Cygni) and Vega (Alpha [α] Lyrae).

Deneb, a magnitude 1.3 bluish-white star, marks the tail of Cygnus the Swan, one of the brightest and most easily recognized of all constellations. The primary feature of Cygnus is the Northern Cross, a giant asterism marked by Deneb, Sadr (Gamma [γ] Cygni), Albireo (Beta [β] Cygni, at the swan's nose), and several bright stars marking the bird's wings. If you have binoculars, take a look at the open cluster M-39, a large scattered group of stars in northeastern Cygnus — you should see a couple of dozen bright white stars in an area approximately equal to half that of the Full Moon.

Several small but beautiful groups of stars surround Cygnus in nearly all directions; the brightest is Lyra the Lyre, whose brightest star Vega shines at magnitude 0. The constellation is shaped like a parallelogram, with a triangle — containing Vega and the multiple star

Epsilon (ε) Lyrae — added at one corner. When viewed with binoculars, the star Epsilon resolves into two separate components; when viewed at high power with a telescope, each of the components resolves into a double star. Epsilon Lyrae is thus a quadruple star; it is nicknamed the “double-double.” The combined magnitudes for each pair are 4.4 and 5.1; the separation of the two main stars is 208”.

Southeast of Cygnus are three small groups of stars. Sagitta the Arrow is a tight arrangement of fourth-magnitude stars. The brightest star in Sagitta is Gamma (γ) Sagittae, a cool, reddish giant of magnitude 3.7. Delta (δ) Sagittae is a spectroscopic double star with a total magnitude of about 3.8, and Sagitta's alpha star, a yellowish object, glows at magnitude 4.4. Delphinus the Dolphin is a small but bright kite-shaped grouping of fourth and fifth-magnitude stars. Alpha (α) Delphini is a bluish-white magnitude 3.9 star; nearby Gamma (γ) Delphini is a subgiant star whose orange color is easily detected. Gamma is a telescopic double star with a combined magnitude of about 4.

Extending a line from Sagitta through Delphinus, we come to the small constellation Equuleus the Horse. This is a tiny group of fourth and fifth-magnitude stars, which might be easy to overlook on a night lacking in transparency. Nevertheless, its brightest star, Alpha (α) Equulei, is a spectroscopic binary of

magnitude 4.1 and is easily locatable in binoculars.

The dominating feature of the fall sky is the giant asterism called the Great Square. Composed of four stars of magnitudes 2 and 3, the square makes up a large part of Pegasus the Winged Horse, one of the great mythological figures in Greek legend. The brightest of the four stars actually belongs to neighboring Andromeda, but remains a feature of the square, as it once was a star in Pegasus. Known as Alpheratz (Alpha [α] Andromedae), the star shines at magnitude 2.0 and is bluish-white. It marks the northeast corner of the great square; in the southeast corner is the star Algenib, Gamma (γ) Pegasi, which shines at magnitude 2.8 and is slightly variable in brightness. The other two stars are Markab, Alpha (α) Pegasi, a magnitude 2.5 star on the southwest corner, and Scheat, Beta (β) Pegasi, a ruddy variable star whose light fluctuates between magnitudes 2.4 and 2.7.

The constellation Pegasus also contains other notable stars. Matar (Eta [η] Pegasi) is one of a group of relatively bright stars near Scheat. It is a Sun-like star of third magnitude. A trail of bright stars leads from Markab to Enif (Epsilon [ε] Pegasi), the “nose” of the horse — a K-type star of magnitude 2.4. See what color you think Enif is in your binoculars. And while you're in the area, scan a short distance northwestward: the small globular star cluster M-15 should appear in binoculars



Cassiopeia

Cepheus

Auriga

Double
Cluster

Perseus

Lacerta

Taurus

Triangulum

M-31

Pleiades

M-33

Andromeda

Aries

Pegasus

Orion

Pisces

M-15

Equuleus

Eridanus

Cetus

Aquarius

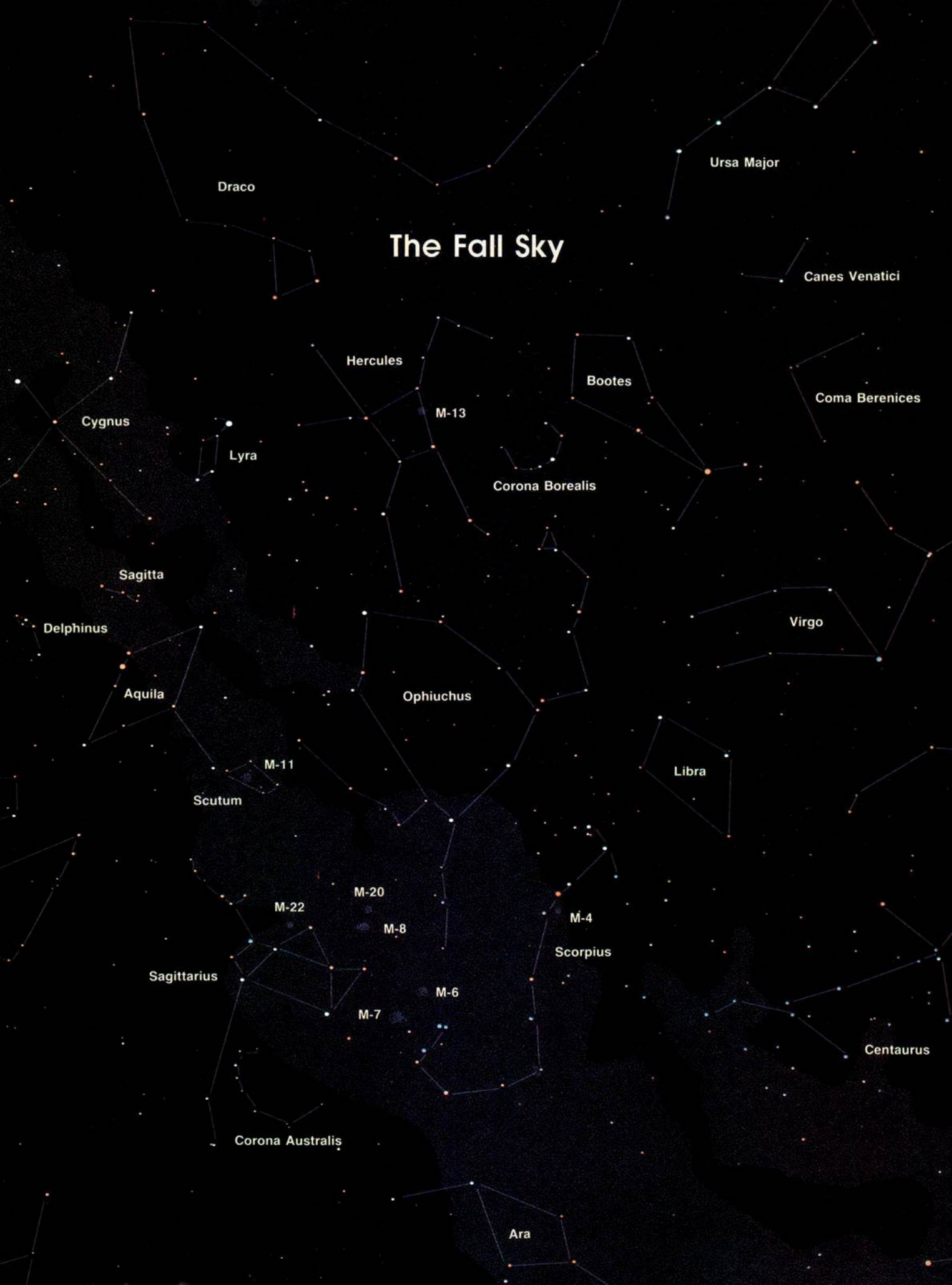
Fornax

Capricornus

Piscis Austrinus

Phoenix

Grus



The Fall Sky

Draco

Ursa Major

Canes Venatici

Coma Berenices

Boötes

Corona Borealis

Hercules

M-13

Cygnus

Lyra

Sagitta

Delphinus

Aquila

M-11

Scutum

Ophiuchus

Virgo

Libra

M-20

M-22

M-8

M-4

Scorpius

Sagittarius

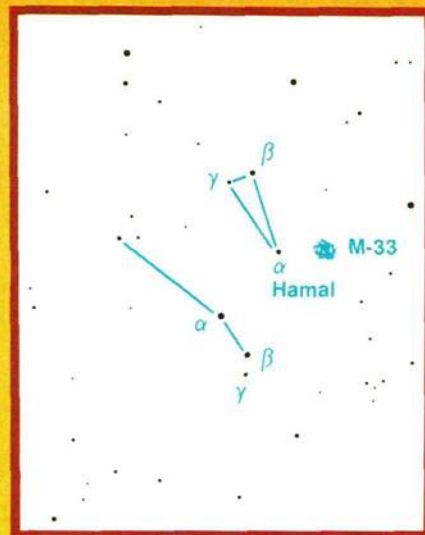
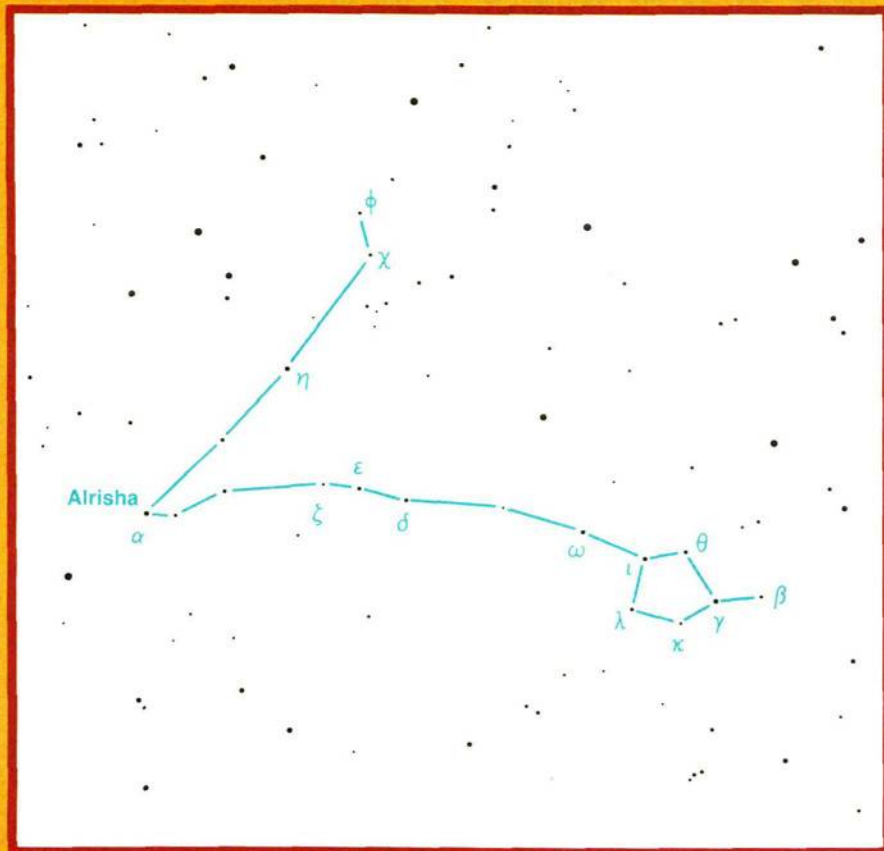
M-6

M-7

Centaurus

Corona Australis

Ara



Left: Pisces the Fish is a large, rambling constellation whose member stars are all of fourth magnitude and fainter. **Top: The two tiny constellations Aries the Ram and Triangulum the Triangle** get passed over by many observers. Aries contains Hamal, Alpha Arietis, an orange-colored star shining at magnitude 2. Triangulum contains M-33, one of the nearest galaxies — look for it in binoculars.

as a fuzzy spot of milky light. This is one of the many spherical collections of old stars that occupy our Galaxy's extensive halo.

Connected to Pegasus by virtue of Alpheratz is Andromeda the Chained Maiden, a constellation consisting of two more or less parallel chains of bright stars. The two chains have a common origin at Alpha, and fan northeastward, toward the bright sprinkling of blue-white stars making up the Perseus association. Besides Alpheratz, bright stars in Andromeda include Mirach (Beta [β] Andromedae), a reddish star shining at second magnitude, and the bright triple star Almach (Gamma [γ] Andromedae), one of the brightest of the sky's multiple star systems. Appearing as a single star to the unaided eye and binoculars, the three stars are separated by only 10"; the brightest individual star in the system is a yellow sun of magnitude 2.1.

Lying within the constellation Andromeda is the most distant object visible to the naked eye — M-31, the Andromeda Galaxy. When the nights are transparent, it is visible as an elongated fuzzy patch of light near the star Nu (ν) Andromedae. Along with the Milky Way, this object is a member of the Local Group of galaxies. Slightly larger than our Galaxy, it lies about 2.2 million light-years off. As you look at it, remember that the light you are seeing emanated from M-31 before our species was born here on Earth. If you have binoculars, you will be able to get

a good view of the galaxy's yellowish core and perhaps even faint nebulosity extending outward, which in actuality are spiral arms. M-31 has two faint satellites in the same binocular field; you may see them as fuzzy little balls of light nearby.

The diminutive grouping of stars called Triangulum the Triangle lies near Andromeda. This constellation is one of the smallest, consisting chiefly of three moderately bright stars. Alpha (α) Trianguli is a magnitude 3.4 star of yellowish color, Beta (β) Trianguli is a third-magnitude white giant, and Gamma (γ) Trianguli shines at magnitude 4.1 and also gleams white. The only noteworthy object in the area is the bright galaxy M-33, another spiral in the Local Group. This galaxy has a high total brightness, but its light is spread over a large area — consequently, it is rather difficult to see in small binoculars. Owners of large binoculars shouldn't have too much trouble finding its soft glow.

South of Triangulum is the larger constellation Aries the Ram, whose brightest star Hamal (Alpha [α] Arietis) is a star with a noticeable orange tint. Beta (β) Arietis, known as Sheratan, has a magnitude of 2.7. Gamma (γ) Arietis, or Mesarthim, is one of the finest double stars for small telescopes: its components are separated by 8" and have a combined brightness of magnitude 5. They are too close to resolve comfortably with binoculars.

Pisces, Aquarius, and Capricornus are

all bright zodiacal constellations prominent in the fall sky. Pisces the Fish contains a handful of fourth and fifth-magnitude stars that are pretty run-of-the-mill. Alpha (α) Piscium, Alrisha, is a double star, but is too close to separate with binoculars. Aquarius the Water-Bearer is a bit more interesting, as it contains Sadalmelik (Alpha [α] Aquarii), a Sun-like star of third magnitude; Sadalsud (Beta [β] Aquarii), a 3.1 magnitude star, also Sun-like; Sadachbia (Gamma [γ] Aquarii), a fourth-magnitude white star, and a goodly number of fourth and fifth-magnitude stars. Capricornus the Sea-Goat, a bright oddly shaped grouping, contains the beautiful binocular double star Giedi (Alpha [α] Capricorni), which is a chance alignment rather than a physically associated pair. The two stars are of fourth magnitude, and both appear to be Sun-like in spectral type. Beta (β) Capricorni is the star Dabih, a true binary star whose separation is 205"; the components are of magnitudes 3 and 6. Delta (δ) Capricorni, Deneb Algedi, is the third-magnitude variable star that marks the tail of the goat.

We've now looked at the winter, spring, summer, and fall skies — all the constellations in the sky except the far northern and southern ones. We'll conclude with two final installments — looking north and south to catch the polar regions wherein lie some of the most curious stars and deep-sky objects the heavens has to offer.

ASTRONOMY

Reviews

Solar Prominence Filter

Lumicon, Inc.
\$495.00

Lumicon's 1.5 Angstrom Solar Prominence Filter sells for under \$500 and includes a 3-inch diameter energy rejection filter. It is very streamlined and compact, so chances are you won't have to make any changes in your scope's focusing mount to compensate for its thickness. The Lumicon filter needs no electrical power to keep it at a constant temperature, and it works equally well with refractors or mirror-lens systems; I did not test it on a Newtonian reflector.

It can be used with your 2-inch focuser or your standard 1¼" eyepiece holder. You can also mount your SLR to it just as easily by using an appropriate T-adaptor. Lumicon has refined its H α filter to the point that anyone interested can get seriously involved in solar astronomy at a reasonable cost. Although it is not intended to compete with the higher priced 0.07A to 0.08A ultra-narrow band-pass filters in terms of resolution or contrast, I was very impressed with what it did reveal.

When I tested the filter last November, there was little visible activity on the surface of the Sun. In fact, at one point, I saw no sunspots in either white or H α light. One day, just as I was about to close up shop, I took a final look and found a large prominence group on the Sun's east limb. The Lumicon revealed it in my 4-inch SCT with no difficulty except for some background scattered light, which may have been due in part to my makeshift off-axis mask or perhaps some dust within the system. (Dust can wreak havoc with these filters.)

Next, I attached it to my 5-inch refractor, and the detail was even more spectacular — one of the best performances I've seen on the Sun in years! Even my "reference standard" 0.08 A H α filter did not reveal much more, except for slightly greater contrast. (Using the 0.08 A filter, I was

able to track that group across the face of the Sun during the following week, which the Lumicon 1.5 A filter could not do.)

The Lumicon is temperature-sensitive and works best at temperatures above 70° F. Although I was testing it when the temperature was barely 50° F, it worked just fine with no special tilting adjustments or auxiliary heating required. Apparently the warm beam of sunlight focused on the heat-absorbing glass filter placed just in front of the H α filter was enough to keep it operating perfectly.

A simple white nylon screw at the eyepiece end tilts the H α filter for fine tuning. I adjusted it several times but could not detect any improvement in contrast or resolution; at the same time it didn't hinder observations. Those prominences, and others I've observed with this filter during the following weeks, seemed just as sharp with or without adjusting this screw. Lumicon also advises masking your scope to f/20 or so; I found masking it down to f/30 gives much better contrast and detail, and in my opinion is much safer. A 30mm eyepiece gave best results, and attaching my SLR was very easy.

All right — how good is it? It isn't up to the quality of my reference standard — but, after all, you only get what you pay for. And Lumicon was honest about the limitations of the filter I tested. This filter is well worth its comparatively moderate price. *Don Trombino.*

Mark-III Prominence Viewer

Roger W. Tuthill, Inc.
\$315.00

If your aim is to glimpse solar prominences, if you don't particularly want to photograph them, and if you have plenty of patience, then consider Roger Tuthill's economical Mark-III, a 3 to 4 Angstrom half-band-pass viewer that sells for about \$300. The one I tested was pre-centered at about 6563.5 Å, the

wavelength of hydrogen-alpha. This lightweight unit consisted of only two parts, the first being a simple filter cell with two rubber rings at one end. These are used to tilt the filter in order to center it as close as possible on the H α line of the spectrum.

The second component, a 32mm binocular-type eyepiece with white diopter markings, focuses sharply on a flat black occulting disk glued to the lower end of the eyepiece. This disk blocks out the bright solar surface and greatly increases contrast by simulating a partial eclipse of the Sun. If you buy this item, I suggest you spend a little more for an energy rejection filter, or ERF. Contrast will be greater and your H α filter will probably last longer because you'll greatly reduce chances of bleaching the delicate coating of your primary filter.

More complex and costly ultra-narrow-band filters are housed in temperature-controlled mini-ovens to keep them thermally stabilized and accurately centered on the very narrow H α line. For his Mark-III filter, Tuthill says that no ERF or heating is required — you "fine tune" only by tilting the filter. This keeps its cost down, of course, but all these filters are temperature-sensitive to some extent. The Mark-III yields better contrast at temperatures of 70° F and above, although I've used it at 40° to 55° F with fair results. The Mark-III filter likes its comfort, and cupping your hand around it helps overcome temperature problems. At the same time cupping your hand blocks stray light so your eyes can dark-adapt to the deep red H α image.

You'll be able to do the necessary tilting in your standard 1¼" eyepiece holder, but unless you have a sturdy equatorial mount with a good clock drive to keep the occulting disk perfectly centered over the Sun, I don't recommend using it for photography. You'd have to be a contortionist to track, focus, and shoot through your SLR and still manage the cupping techniques.

When you order a Mark-III filter, you must specify the focal ratio of your scope ($f/8$, $f/10$, $f/15$, etc.) so that the right occulting disk can be constructed for your particular set-up. This means the filter is not easily interchangeable with other telescopes with different focal lengths. For example, if you normally use it with an $f/10$ scope but decide to try it with another telescope of equal aperture but having, say, an $f/15$ focal ratio, you'll find the occulting disk won't cover the larger circumference of the Sun's limb.

In my case, I reduced the lens opening in the telescope to give me a comfortable $f/30$ light beam. Bright prominences could be seen around the artificially eclipsed Sun — at times, even under less than favorable sky conditions. Tutthill suggests, and I agree, that dark blue skies offer the best conditions for observing with his viewer. His 32mm eyepiece gave me clear images of bright-red prominences silhouetted against the blackness of space, but only when the occulting disk completely covered the face of the Sun. The Mark-III "viewer" is aptly named; don't expect to see much more than prominences, especially at this low price.

Properly used, this $H\alpha$ viewer should provide many pleasant hours of daytime observing for casual observers, students looking for an unusual science project, or industrious and imaginative individuals skilled enough to construct a real prominence telescope. If you decide to build one using this filter as the heart of your system, be sure to incorporate various sizes of occulting disks to compensate for the changes in the Sun's apparent diameter from one season to another. *Don Trombino.*

Bigfoot Telescope Mounting

The Image Point, Inc.

Prices vary: \$350 to \$500

Amateurs looking for a reasonably priced yet highly stable mount will be interested in a product from The Image Point of Tucson, Arizona. These people have developed a unique mounting called "Bigfoot," available for both Newtonian and Schmidt-Cassegrain reflectors. Created and built by Pierre Schwaar, a well-known ATM and astrophotographer, the Bigfoot is a wooden German equatorial, with optional motor drive and a gear made of Formica.

The Bigfoot is intended for both visual and photographic use; it can be disassembled in about 10 minutes into several pieces that fit into a moderately sized car. The mount is available in four models. Two versions carry Newtonians — the smaller for 6 to 10-inches, the larger for 10 to 17-inches. Similarly, Cassegrains or Schmidt-Cassegrains ride comfortably on Bigfoots (Bigfeet?) of somewhat taller design.

The mounting arrives in a few sections that assemble with a wrench. Instructions

are plainly written and easy to understand. A nice feature is that once the mount is assembled, it comes apart in two sections — the upper part, with the tube mounting rings, and the lower, with the equatorial head and three legs. The rear leg folds inward, with no need for tools or disassembly, so that it swings parallel to the front legs. Then the mount fits into the back of a car. I have seen even the largest mount fit neatly into a station wagon with room to spare.

When you set up the mounting, it aligns on the pole easily. All you have to do is adjust the angle of the rear leg assembly. Mounts can come fitted with a special adjusting screw for more permanent polar alignment. The motor drive then plugs in, you do the fine-tuning adjustment on the pole by star-drifts, and you're all set.

I was really impressed with Bigfoot's ability to damp out bumps. Using a large SCT, I found that star images stopped shaking in only 2 or 3 seconds, compared with the 10 to 15 seconds I got when I tried the same experiment with the telescope's factory-built mounting. On this mount, the telescope's motions have a good, firm feel to them.

The Bigfoot comes with optional hand-operated or electric slow-motion controls. The electric declination motor is available either in AC or DC, and moves the telescope in dec at the rate of five arc-seconds per second. The main right ascension drive can be controlled by a drive corrector to provide the faster and slower speeds.

Limitations? I noted two: First, some people may prefer to have the mount disassemble farther, so that you could store it more easily in a tiny car. Second, since much of the mount is made of wood, it must be handled carefully.

What about weight? To get stability, you'd expect that a wooden mount would be rather heavy, but actually it isn't. In fact, the smaller one is quite transportable, being somewhat lighter than most of its less stable counterparts.

If you are a beginner, whose first 6- or 8-inch telescope probably has excellent optics but a wobbly mounting, you may benefit from a Bigfoot because the increased stability will make your telescope easier to use. And once you become more experienced, you'll like the Bigfoot's clean, vibration-free images and steady base for astrophotography. *David H. Levy.*

Reviews of Infrared and Millimeter Waves, Volume 1

Kenneth J. Button, ed.

372 pages, hardcover, \$45
Plenum (1983)

This is the first book in a series on infrared and millimeter waves, each of which will contain the manuscripts of invited papers from conferences on the subject. This volume consists of papers

from the 20th General Assembly of the Union-Radio-Scientifique Internationale, held in Washington in 1981. Topics discussed include ultra-low-noise millimeter wave receivers, the free electron laser and gyrotron, measurements of noise power, complex dielectric properties of solids and liquids, and radioastronomy.

Introduction to Plasma Physics and Controlled Fusion

Volume 1: Plasma Physics

Francis F. Chen

421 pages, hardcover, \$24.50
Plenum (1984)

One of the pioneers of this rapidly expanding field offers both a simple and intuitive discussion of its basic concepts and an insight into the challenging problems of current research. In this revised edition of the original (1974) work, Chen includes new material on kinetic effects, nonlinear wave equations, and solitons. The second volume, still being planned, will explain the principles of magnetic and inertial confinement, as well as introductions to tokamaks, tandem mirrors, and alternate concepts.

The Illustrated Encyclopedia of the Universe

Richard S. Lewis *et al.*

320 pages, hardcover, \$24.95
Harmony Books (1983)

This large-format work consists of chapters — authored by different research specialists, such as Stephen Strom, Stephen Maran, and Thornton L. Page — which treat the topics of galaxies, stellar evolution, cosmology, the Sun, the planets, and the future in space with concise writing and dozens of color photos and illustrations.

Worlds in Comparison

Stephen P. Meszaros

15 slides and explanatory booklet
Astronomical Society of the Pacific (1983)

The 15 slides in *Worlds in Comparison* graphically show the range of sizes of moons and planets in the solar system. Included are several false-color radar views of planetary surfaces, a map of the U.S. overlapping Mars' Valles Marineris, views of Phobos and Deimos compared to New York's Manhattan Island, and Earth superimposed onto various planets.

Early Man and the Cosmos

Evan Hadingham

271 pages, hardcover, \$22.50
Walker and Company (1984)

This book examines the relationship between primitive cultures and the stars.

The heavens significantly affected how they lived, worked, and worshipped, and told them when to plant crops and take other actions. The book investigates Stonehenge, the Mayan temples, Pueblo lore and legends, and many other aspects of early man's conception of the cosmos.

Astronomy: Fundamentals and Frontiers, 4th edition
Robert Jastrow and
Malcolm H. Thompson
564 pages, hardcover, \$30.95
Wiley (1984)

The fourth edition of this popular college text for non-science majors covers historical ideas about astronomy, telescopes and equipment for research, solar system astronomy, the Milky Way and its dynamics, and the large-scale structure of the cosmos, including clusters of galaxies and quasars.

Realm of the Universe, 3rd edition
George O. Abell
466 pages, softcover, no price given
Saunders (1984)

The third edition of the late George Abell's popular college text includes chapters on radiation, the planets, distances and motions of stars, relativity, gas and dust in the Milky Way, galaxies, quasars, and cosmology. Exercises follow each chapter, giving students practice with problems in determining brightness, distance, velocity, etc.

Wonders of the Sky
Fred Schaaf
299 pages, softcover, \$6.95
Dover (1983)

Rainbows, comets, eclipses, bright stars and planets, and other naked-eye celestial sights comprise the bulk of this book about backyard observing. A manual of techniques for spotting these phenomena, *Wonders of the Sky* contains many photographs and several star charts that cover the northern sky.

An Introduction to Experimental Astronomy, 2nd edition
Roger B. Culver
196 pages, softcover, \$9.95
Freeman (1983)

A workbook of practical exercises in observational astronomy, this book provides the background needed to carry out 22 experiments with a telescope. Included are problems on determining the speed of light, basic photometry, the motion of Barnard's Star, parallax measurements, the distance to galaxy M-87, determining the Hubble Constant, and properties of quasars.

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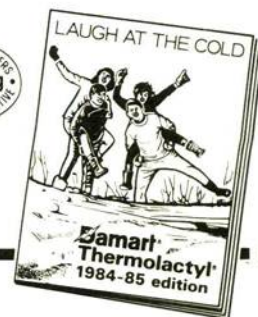


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Bright Planets Abound

by
Fred Schaaf

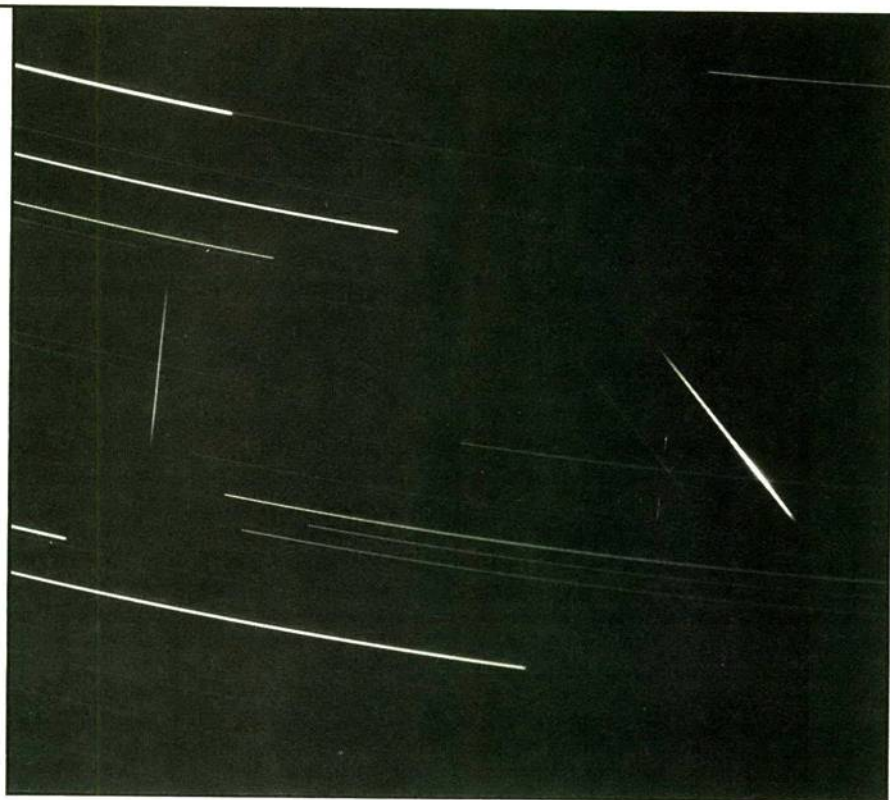
The Wanderers

Each of the bright planets puts on a fine show this month. Mercury undergoes its finest morning apparition this year. Mars races between Antares and Uranus on its way through the constellation Ophiuchus. Jupiter floats above the Teapot of Sagittarius. Venus shines brilliantly and hovers north of Spica. And Saturn, the golden ringed world, remains easily visible in Libra.

The pre-dawn sky is free from other planets, making **Mercury's** morning performance a solo show. The planet lies near Regulus during the first half of September; a conjunction, when Mercury is $1^{\circ} 36'$ south of the star and somewhat brighter, occurs on the morning of the 8th. On the 14th Mercury reaches a greatest elongation of 17.9° — almost the minimum possible greatest elongation. Almost vertically above the Sun, Mercury rises 90 minutes before sunup.

Mercury is at perihelion on the 16th and at greatest latitude south of the ecliptic (7°) on the 26th. The planet is flanked on either side by the asteroids Vesta and Juno, which follow parallel paths on either side of the ecliptic and are visible in binoculars. Of course, neither is really observable until next month, when they are up well before morning twilight. Mercury, on the other hand, is visible until late in the month — it then brightens to magnitude -1 on its way to a superior conjunction on October 10.

In the crowded evening sky, **Mars** is the central planet and is striking at magnitude 0 as it passes eastward above the back of Scorpius. On the 2nd and 3rd Mars is almost exactly midway between Uranus and Antares. The ruddy planet lies $2^{\circ} 23'$ south of sixth-magnitude greenish-blue Uranus on the evening of the 2nd, and is



$2^{\circ} 15'$ north of first-magnitude ruddy Antares after they set on the American evening of the 3rd. All month long Mars is prominent in the southwest evening sky, at an elongation between 80° and 90° from the Sun.

Easily outshining Mars is brilliant **Jupiter**, which slowly begins to accelerate with direct (eastward) motion back toward Lambda (λ) Sagittarii, the dome of the Teapot. On the 17th of this month, Jupiter achieves its most southerly declination, -23.5° . Mars will not come back to this point for another dozen years. Next month Mars will overtake the -2 magnitude planet Jupiter for a superb conjunction right at the top of the Teapot.

For the moment, September is the last month for good viewing of **Saturn**. The planet shines at only about magnitude 0.8, but is still 40° east of the Sun when, on the 20th, it lies a mere 5 arc-minutes north of 5.4 magnitude Mu (μ) Librae. As the month ends, Saturn is almost due north of Alpha (α) Librae and little more than 2° from that star.

A final naked-eye planet is rather poorly placed, but deserves a look because it outshines the others. **Venus** continues its slow return to good visibility in the evening sky. Its progress for North American and European observers is hindered by its movement toward the more southerly reaches of the zodiac. To make matters worse, Venus crosses south of the ecliptic on the 30th.

On the 19th you may need binoculars to get a good look at Spica, almost 3° south of magnitude $-3\frac{1}{2}$ Venus. You will

On August 12, 1981, during the height of that year's Perseid meteor shower, Dan and Nancy Ostergaard captured three meteors — roughly perpendicular to the trailed stars — as they burned up in Earth's atmosphere. They used a 12-inch $f/2.5$ Aero-Ektar lens and $8" \times 10"$ Tri-X sheet film for the 37-minute exposure.

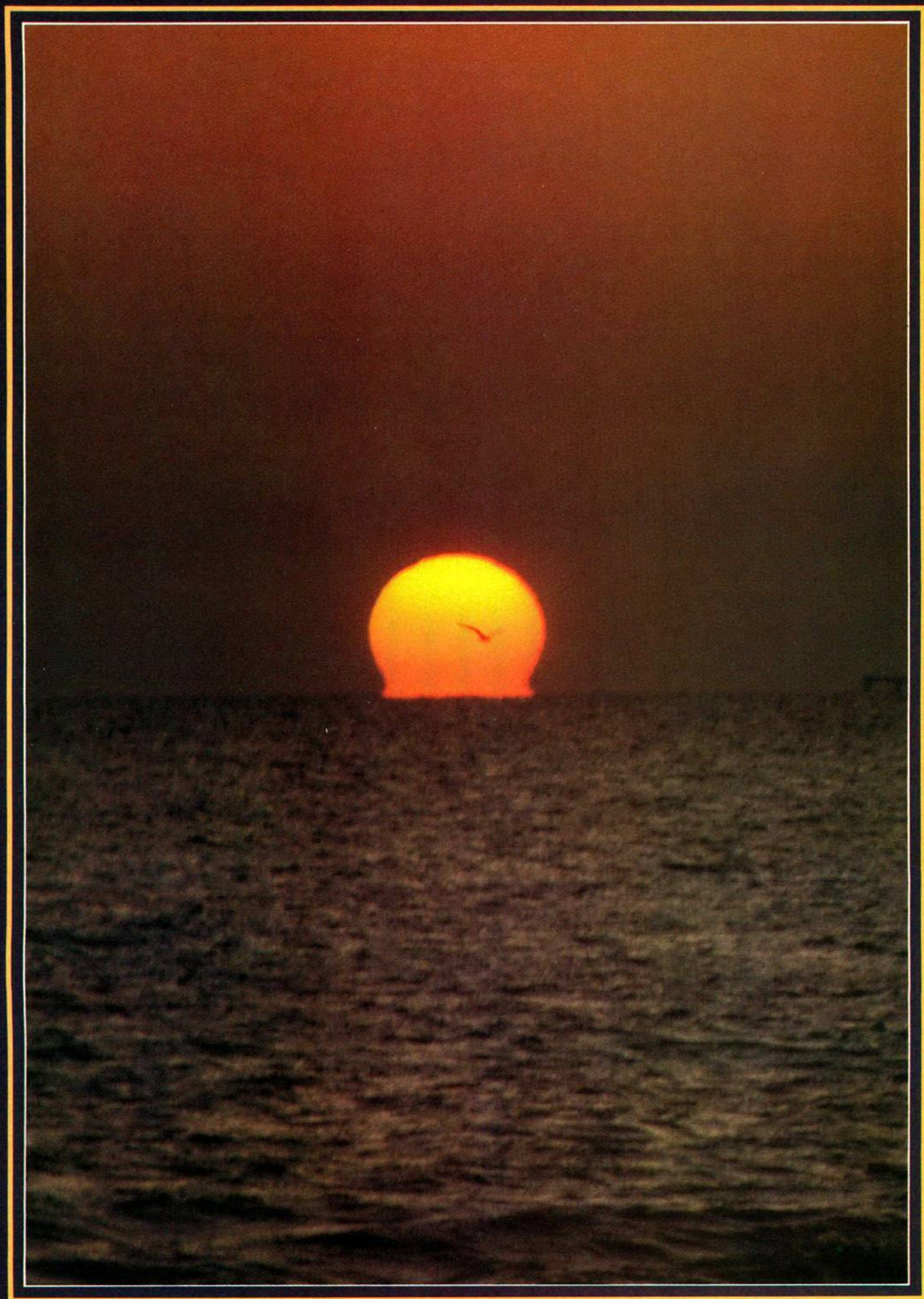
Accompanied by a lone seagull early one Virginia morning, Geoffrey Belet recorded this scene showing sunrise over Chesapeake Bay. He used a 300mm telephoto lens at $f/5$ and a $\frac{1}{125}$ -second exposure on 64 ASA emulsion. The Sun's distorted shape is caused by differential refraction in the atmosphere.

not need binoculars to detect a beautiful pairing of the Moon with Venus on the evening of the 26th — as a matter of fact, you have a remote chance of glimpsing a less-than-one-day-old-Moon the previous evening. A good opportunity to see an even thinner crescent from the eastern United States occurs on the morning of the 24th, when the Moon is only about $6\frac{1}{2}$ hours from New Moon at sunrise on the East Coast.

The New Moon that occurs between these two slivers is a notable one — not because it causes an eclipse, but because it should cause high tides. New Moon occurs at 13:11 UT, within an hour of the time the Moon is at a close perigee.

The Full Moon occurring nearest to the September equinox is usually called the Harvest Moon. This year the equinox happens at 4:34 p.m. EDT on the 22nd,

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.



Star Dome



The
Star Dome
shows how the
sky looks at:

11:00 p.m. on September 1
10:00 p.m. on September 15
9:00 p.m. on September 30

September Sky Almanac



- 2nd** First Quarter Moon is at 6:30 a.m. EDT. Mars lies 2° north of Antares tonight.
- 4th** Mars passes 2° south of Uranus; both are in southern Ophiuchus.
- 8th** Look for Mercury and the star Regulus together in the eastern sky this morning during the hour before sunrise.
- 10th** Full Moon (Harvest Moon) is at 3:01 EDT (see text).
- 11th** The Moon is at apogee at 9:26 EDT: 252,509 miles.
- 14th** Mercury is at greatest western elongation this morning — look for it low in the eastern sky shortly before sunrise. From now until it disappears into the glare of sunlight around the end of September, it will appear a little lower each morning. Mornings in the fall are also the best time to look for the zodiacal light — a soft glow sometimes called the “false dawn” that is visible as a triangular band of light extending upward from the horizon along the ecliptic. But don’t look for it except under dark country skies — it’s much too dim.
- 16th** Mercury passes through perihelion today.
- 18th** Last Quarter Moon is at 5:31 a.m. EDT.
- 22nd** The autumnal equinox occurs at 4:33 p.m. EDT: fall begins in the northern hemisphere.
- 24th** The Moon is at perigee at 10:51 p.m. EDT: 221,807 miles.
- 25th** The Moon is New at 11:11 p.m. EDT.



Full Moon closest to it is the one on September 10th. On nights around the 10th the Moon rises in Aquarius and Pisces, where the ecliptic (and the Moon's approximate path) is highly inclined to the eastern horizon. As a result, on successive nights the Moon rises at more or less the same time. Instead of the average of about 50 minutes later each night at 40° north latitude, the interval is only about 30 minutes. Farther north — in Great Britain — for instance, the interval decreases to 20 minutes and less.

The Starry Sky

Lengthening nights enable us to continue to observe the Sagittarius Milky Way, which we examined last month. More prime targets, however, are the constellations of the Summer Triangle and the first autumnal constellations.

Although they form the so-called Summer Triangle, **Vega**, **Deneb** and **Altair** will be visible in the evening until year's end and beyond at mid-northern latitudes. About a year ago IRAS, the Infrared Astronomical Satellite, detected solid matter orbiting Vega. Could this material be cometary particles in a swarm like the Oort cloud? We'll have to wait for more definitive answers, but IRAS did prove that Vega is by no means unique — about 50 stars near the Sun have similar disks of matter.

Another bright star which IRAS found harboring such a cloud is rising in the southeast — **Fomalhaut**. Vega is 26 light-years distant, Fomalhaut 23. Almost directly opposite to Fomalhaut is another close star, setting in the northwest — **Arcturus**. For a time Vega reigns as the only magnitude 0 star prominent in the sky. But not for long; **Capella**, virtually identical in brightness, soon rises in the northeast. (This year the southwestern September sky is occupied by ruddy, magnitude 0 Mars — and by a much brighter Jupiter.)

Although Vega is prominent, it has passed the zenith of the United States and much of Europe by mid-evening, replaced by the slightly more northerly **Deneb**. This star is not the head but the tail of lovely **Cygnus** the Swan, as its name indicates (Deneb means "tail"). The star appears dimmer than Vega or Altair but is about one hundred times more distant than the latter and so is actually far more luminous.

Like winter's bluish star Rigel, Deneb has an absolute magnitude of about -7 — this is how bright it would be if placed 10 parsecs (slightly more than 32 light-years) away. (Vega and Altair would appear much fainter.) Intrinsically, Deneb is about 60,000 times more luminous than our Sun!

Cygnus is one of the best constellations to scan with binoculars. Mounted binoculars can reveal the gold and blue

From San Juan, Puerto Rico, Wayne Wooten photographed sights unfamiliar to most North American observers: at right center is **Crux**, the southern Cross; at left, near the horizon, are **Alpha (α)** and **Beta (β)** Centauri. Wooten used a 55mm f/1.4 lens, 400 ASA emulsion, and a 30-second exposure.

double star **Albireo** (the Swan's beak), which is a fine object for small telescopes. Under dark skies, 7x50s might even show you a trace of the supernova remnant called the **Veil Nebula**, whose brightest wisps lie near **52 Cygni**, in the Swan's eastern wing. Detectable with the naked eye is the **North America Nebula**, a couple of degrees east of Deneb. Without optical aid it looks like a bright path of Milky Way. Sadr, **Gamma (γ)** **Cygni**, is surrounded by the faint nebulosity **IC 1318**, which may be visible with large binoculars.

Altair appears brighter than Deneb, though it lies in a less dazzling constellation. Aquila the Eagle is primarily noted for Altair and the third- and fourth-magnitude stars **Tarazed** (Gamma Aquilae) and **Alshain** (Beta [β] Aquilae), which lie on either side of it. Look at Altair with binoculars and judge its color; is it as white as Deneb, or not?

Aquila contains a naked-eye variable star, **Eta (η)** **Aquilae**, which is the third brightest Cepheid variable in apparent

magnitude (Delta Cephei and Polaris are brightest, but Polaris' changes are too slight to detect visually). Eta Aquilae brightens from magnitude 4.5 to 3.7 in about two days, then falls back to minimum after about five days. Eta is the noticeable star nearest to the south of Alshain, which is a fine comparison star, at magnitude 3.7.

The small constellations around the Summer Triangle are worth some attention, though naked-eye observers will find them difficult to locate in light-polluted skies. **Vulpecula** is unimpressive without optical aid. You should have better luck identifying the diamond-and-tail shape of compact **Delphinus** the Dolphin, not far northeast of Altair. While Delphinus lies outside the main glow of the Milky Way, a more petite pattern, that of **Sagitta** the Arrow, lies right within the rich Milky Way. Sagitta lies about midway between Altair and Albireo.

Delphinus and Deneb lie on the meridian at about the same time — a time when the head of **Capricornus** the Sea-Goat has already past the meridian. Thus, although Deneb and Delphinus are often considered summer objects and Capricornus an autumn one, Capricornus actually has its brief fling of prominence in September. The head of the Sea-Goat is formed by Alpha Capricorni and Beta Capricorni, which are called **Giedi** and **Dabih**. Giedi is a double star whose components are separable with the naked eye on a good night. Dabih is also a wide double but definitely requires some optical aid to split. At the opposite end of the mostly dim Capricornus is another third-magnitude star, **Deneb Algiedi** — another "tail" star.

Just north of Capricornus are several stars of Aquarius, a constellation better placed next month. But a bit higher above Deneb Algiedi is a very bright second-magnitude star. This is Epsilon (ε) Pegasi, the nose of Pegasus, also named **Enif** ("nose"). It forms a fairly good equilateral triangle with Deneb and Altair.

Although the great horse Pegasus is still climbing, you may want to locate its dim neighbor, **Equuleus** the Little Horse. Equuleus' brighter stars are just south of the line from Enif to Delphinus. A few degrees from Enif on the line from that star to the Dolphin's nose you can find globular cluster **M-15** in binoculars — or possibly with the naked eye under dark skies.

Skylore

Equuleus is the Little Horse or the Foal, and few amateur astronomers would guess that so dim a constellation has such a long history. Equuleus is no modern addition; it appears on the list of 48 constellations compiled by Ptolemy (the 2nd century A.D. Alexandrian astronomer Claudius Ptolemaeus). Although Equuleus was not mentioned in the extant writings



of early Greek commentators, Geminus (who wrote around 77 B.C.) stated that Hipparchos (about 160-120 B.C.) had formed the constellation. But there is no mention of Equuleus in the "Commentary" of Hipparchos.

Ptolemy regarded the stars as only representing the front (or perhaps head) of a horse; the Arabs of the Middle Ages followed this authority and called it Al Kit'ah al Faras, Part of a Horse. From this phrase we derive Kitalpha, the name for Alpha Equulei. By far the brightest star in Equuleus, it is only magnitude 3.9. Two fourth-magnitude stars and two others brighter than 5.5 complete the inventory of those likely to be noticed by a naked-eye observer under dark skies.

Equuleus is even smaller than it is faint — that is, the official boundaries of the constellation contain less area than Sagitta and only a bit more than the smallest constellation, Crux. Nearby Pegasus has almost 16 times as much area — Equuleus is indeed a little horse. Why is Equuleus so small? Ultimately because its stars were probably part of a larger Delphinus in the earlier days of Greek culture.

Equuleus has been identified with various mythological horses, more or less unsatisfactorily. Author R.H. Allen states that the constellation "was connected with the story of Philyra and Saturn." Saturn (Greek Cronus) was an early king of the universe, eventually overthrown by his son Jupiter (Zeus). He lay with Philyra, the daughter of his fellow Titan, Oceanus, but when caught in the act by his wife Rhea, he turned into a stallion and galloped off. Equuleus presumably represents Saturn in this horse-form because the result of the union with Philyra was not a foal but a half man, half horse — in fact the most famous of all the centaurs, Chiron. The nearby constellation Sagittarius is often identified with Chiron.

Other mythologists said that Equuleus was either Celeris, a horse given to Castor by Mercury, or Cyllarus, a horse given to Pollux by Juno. According to Allen, Celeris was said to be the brother of Pegasus, but I am not aware what classical writer made this otherwise unsupported

Oregon's Mount Hood reveals its snow-capped valleys by moonlight in this 60-second exposure on 200 ASA film. John R. Foster mounted his 35mm SLR camera on a sturdy tripod, focused the 50mm lens at infinity, opened the lens diaphragm, and shot the picture. Ursa Major trails above the mountain.

contention. The main tradition about Pegasus is that he was unique and had no equine brother, though the warrior Chrysaor sprang with him from the spilled blood of Medusa.

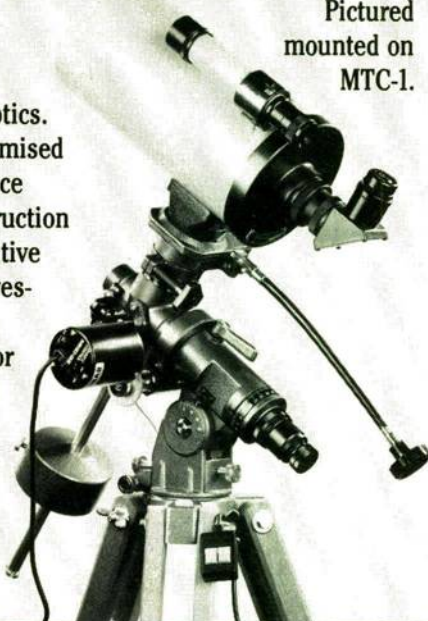
Another horse linked with Equuleus is the very first one. A famous Greek myth tells that Poseidon and Athena were quarrelling over which of them should have a certain young city named for them. Zeus ordered the issue be decided on the basis of who gave the best gift to the people of the city. Poseidon's gift was his creation the horse, an animal previously unknown. But the horse, beautiful and wondrous as he was, was regarded as a symbol of war, whereas Athena's gift, the olive tree, was (and still is, of course) regarded as a symbol of peace. The goddess won the contest and so the city, long after famed for peace, wisdom, and the arts, was named Athens.

In more modern times some of the religious revisionists of the constellations claimed Equuleus was the horse that Haman hoped for in the Book of Esther, and Julius Schiller called it the Rosa Mystica. Equuleus has seldom been considered other than a horse in Western European cultures, though it has been called Hinnulus, Young Mule.

One final note related to Equuleus: there was once another Equuleus, a constellation that still exists. I am referring to the constellation we now call Pictor, whose original and proper name was Equuleus Pictoris. This name means the Painter's Easel, the idea of course being that such an easel resembles a wooden horse. This constellation, as dim as Equuleus itself, is located below Columba and hence is too far south to be known by most North American and European observers.

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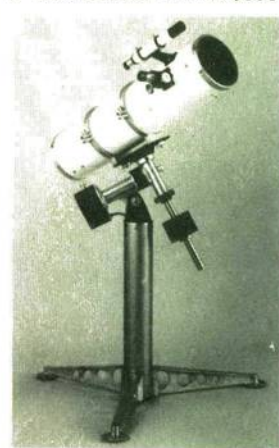


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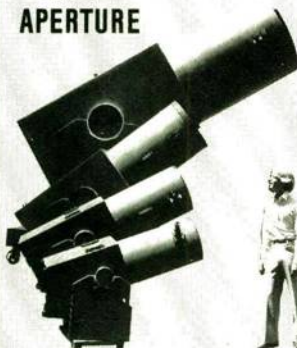
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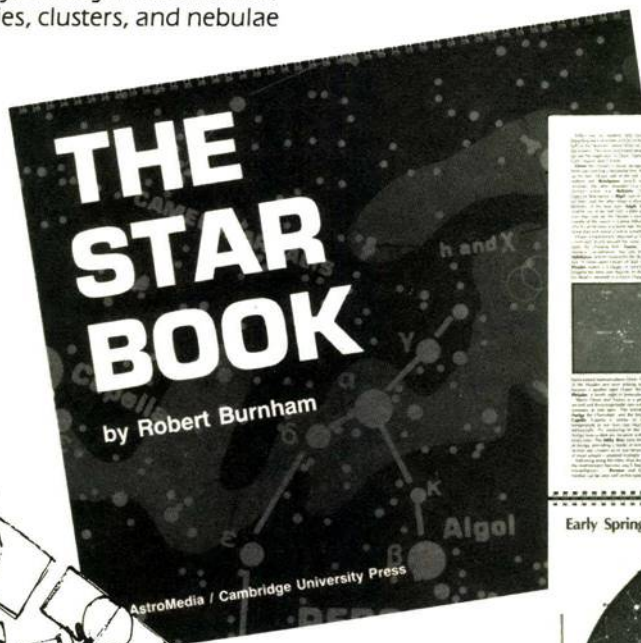
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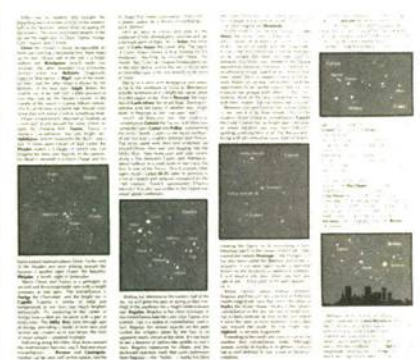
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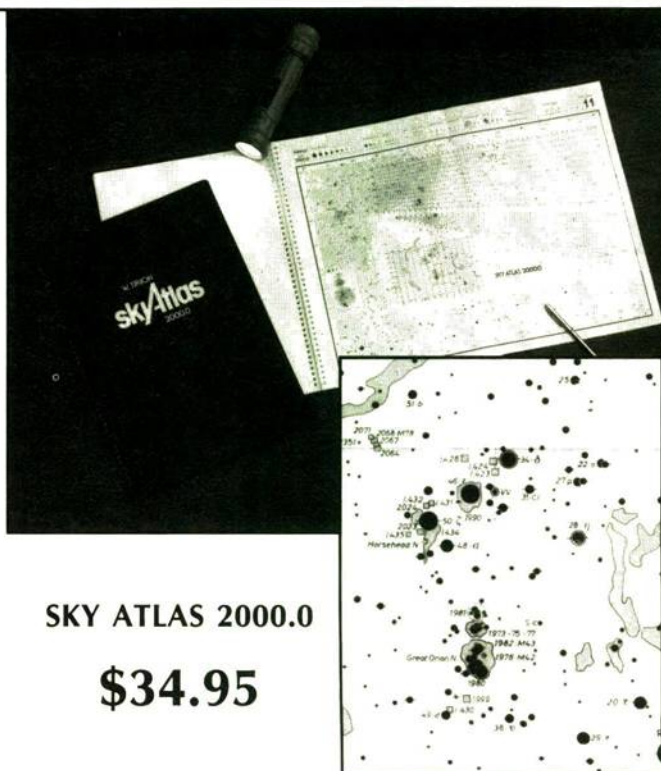
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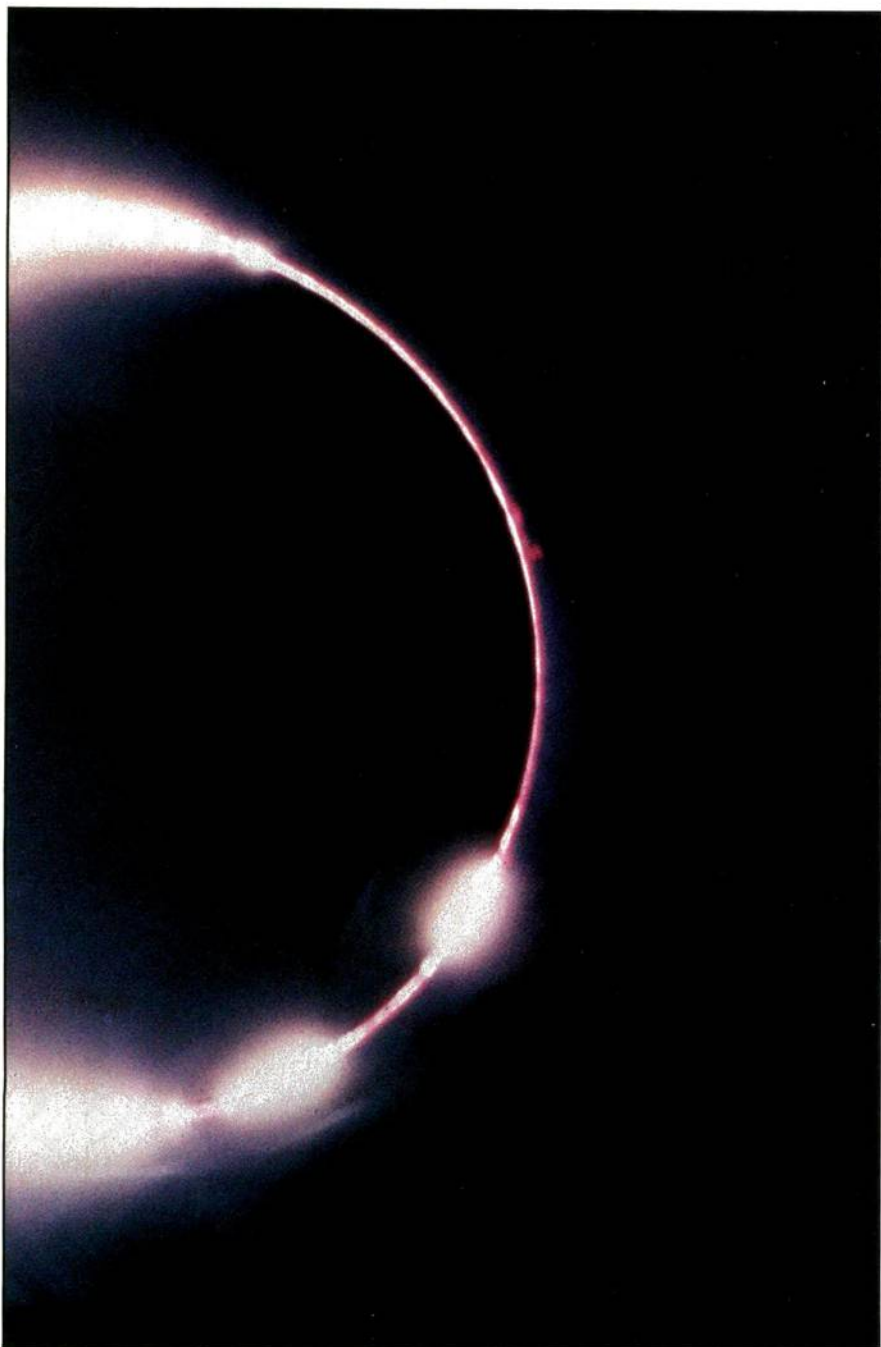
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Sunshow in the Southland

by
Ed Tant

Photography
in
Astronomy



Third contact! Hal Jandorf went to Cleveland, North Carolina, where he photographed the Sun's ruddy chromosphere with a $1/125$ -second exposure on Ektachrome 200 at f/27 with a 5-inch SCT (no filter).

Millions of people throughout the southeastern U.S. were treated to a rare and fleeting annular eclipse of the Sun on May 30, when the shadow of the Moon traced a path stretching diagonally from the Louisiana coast to Chesapeake Bay. Here in Georgia the eclipse swept over small towns like Talmo and Maysville, but large numbers of Atlantans enjoyed the spectacle as well, since the line of maximum eclipse cut through the middle of the city's Piedmont Park. There, science mixed with symphony as eclipse viewers picnicking in the park were treated to an Atlanta orchestra's "Symphony of the Eclipse."

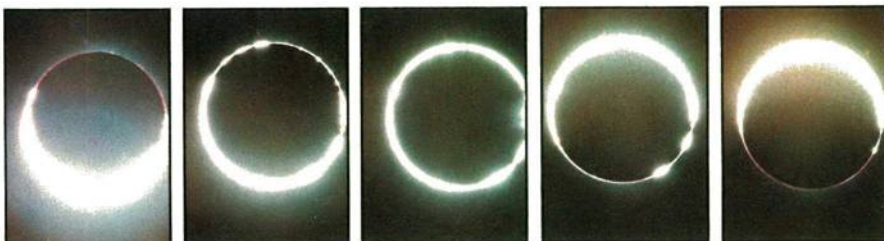
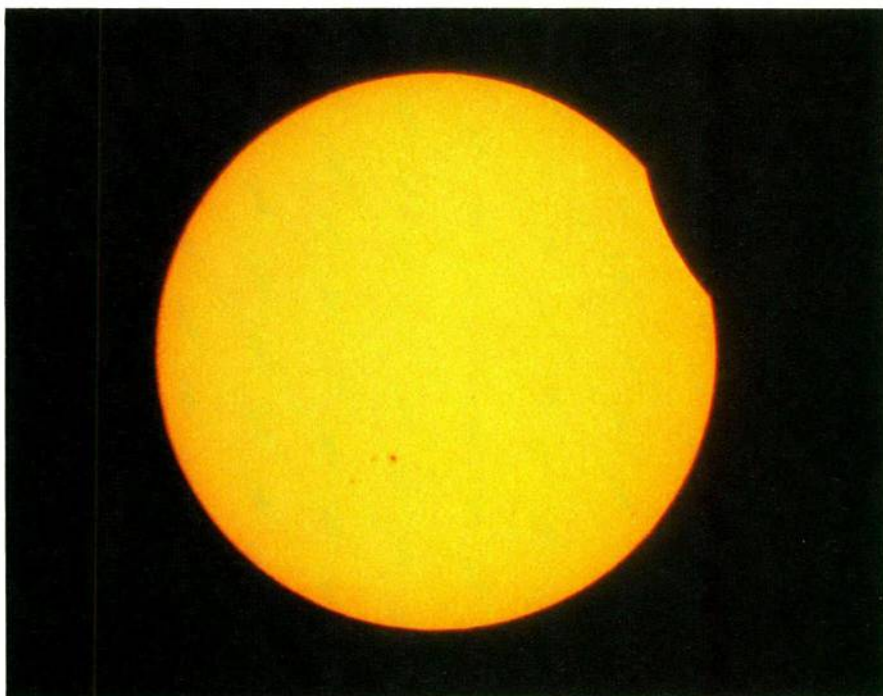
In Athens, home of the University of Georgia, excitement was in the air days before the solar display. Newspapers and radio stations warned observers to use caution, and a local fast-food outlet distributed free Mylar filters to eclipse watchers. These filters caused a mini-feud between professional and amateur astronomers in the area. Dr. Ernest Reuning of the University of Georgia physics department urged would-be eclipse viewers to watch the phenomenon on television, saying, "Go to your favorite beer dive, preferably one that's air conditioned, and watch it on television." He expressed concern for the safety of school children and said that no eclipse was worth ruined eyesight. Most young children were kept inside schools along the eclipse path, but those with parental

Opposite page: Michael Parcheta and Daniel Marcus stationed themselves near Monticello, North Carolina, where they shot this photo showing a prominence above the western limb (top). They used an 8-inch SCT, Plus-X film, and a $\frac{1}{500}$ -second exposure at f/10 (no filter).

This page, top: Soon after first contact as seen from Greensboro, North Carolina, William Schwittek made this photograph showing the intruding limb of the Moon and a sunspot group. He used a 500mm lens, 2x extender, VR 100 film, $\frac{1}{250}$ -second exposure at f/16, and a filter transmitting $\frac{1}{10,000}$ of the incident light.

Middle: The progress of the Moon across the Sun's face was caught in Robert Dixon's sequence, taken from Mooresville, North Carolina. He used an unfiltered 8-inch f/10 SCT, VR 400 film, and $\frac{1}{2000}$ -second exposures. (Note that west is at top.)

Bottom: Alan Havrilla used an 8-inch SCT at f/10, Kodachrome 64 film, and $\frac{1}{30}$ second exposure to catch the broken ring of sunlight. (Mr. Havrilla didn't mention where he observed or what kind of filter he used.)

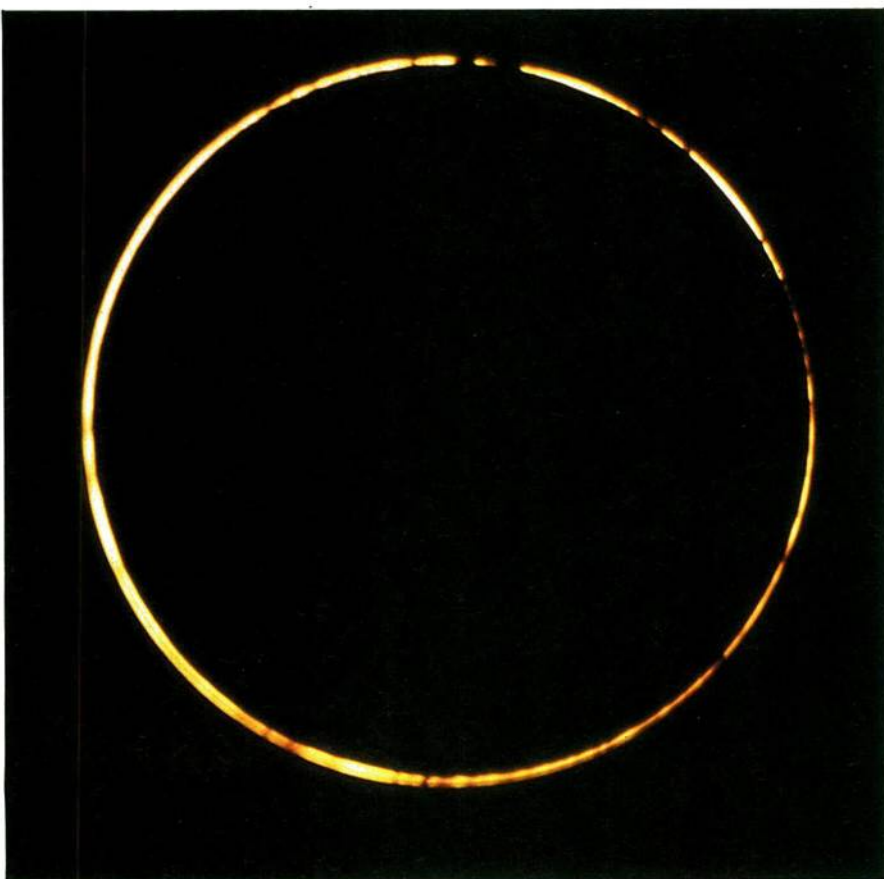


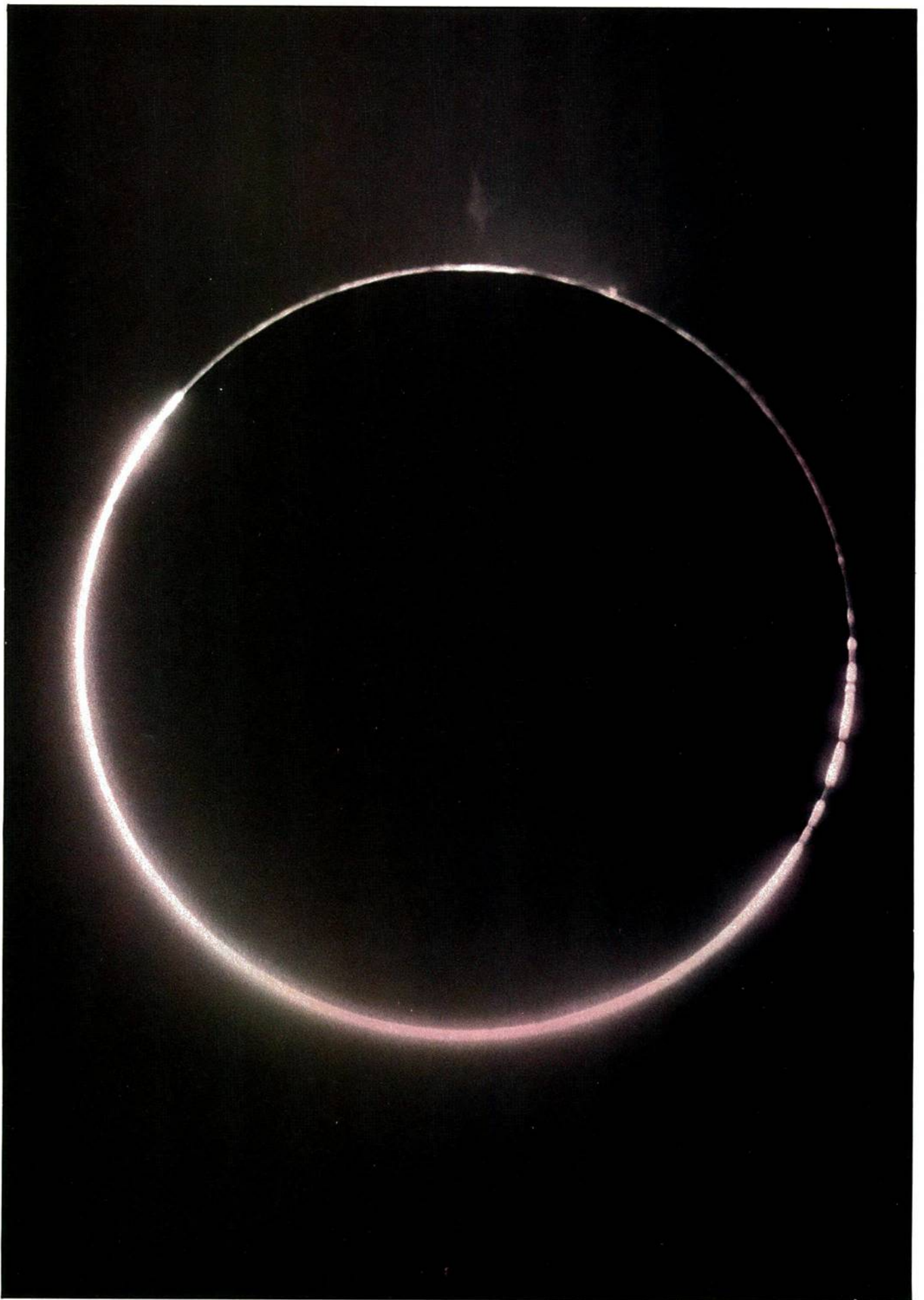
permission were allowed outside to view the event.

The president of the Athens Astronomical Association, Maurice Snook, an eclipse chaser whose photos of past solar eclipses have appeared in the *World Book Encyclopedia*, decried the widespread attempts to keep children inside during the spectacle. Snook visited most of the schools in the Athens area before the eclipse, showing teachers and children safe methods of viewing. He defended the safety of Mylar filters and asked, "Are our children going to learn about nature from television?"

Eclipse day in Georgia dawned crisp and turquoise clear, the kind of weather that every eclipse chaser hopes for. The northeast Georgia town of Maysville was a mecca for amateur astronomers, since the local elementary school was right on the center line of the eclipse path. Celestial voyeurs were invited to set up their equipment on the school's playing field, and principal Andy Byers walked about and chatted with stargazers like some enthusiastic "Mayor of Eclipseville." Pointing upward at the cloudless sky, he commented, "The next thing we want is weather like this when Halley's Comet comes around."

Optical equipment ran the gamut at the Maysville Elementary School. Charalee Sedgwick of Athens focused on the eclipse with her meticulously crafted pinhole camera. Another Athenian, Sam Fariss,





Top: Broken cloud interfered off and on with Erik Einset's photos of the partial eclipse, which he observed from Romulus, New York. But the clouds filtered the Sun enough that he could shoot Ektachrome 64 at $\frac{1}{250}$ second with his 50mm f/14 refractor.

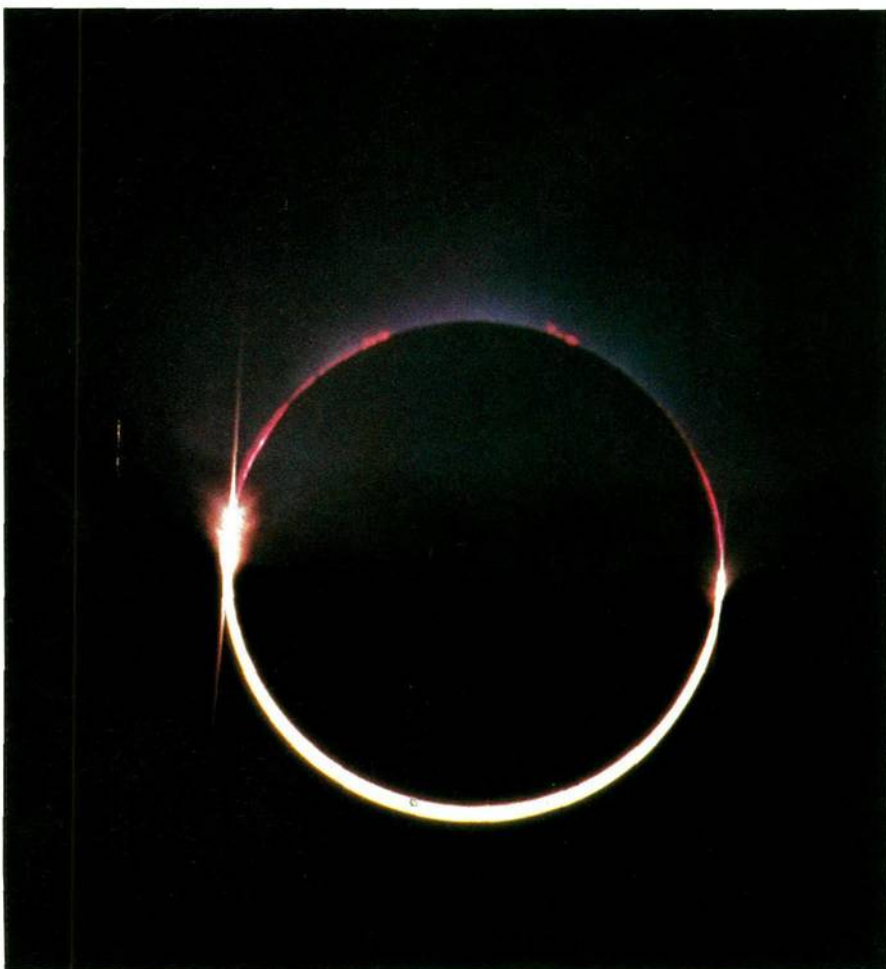
Bottom: Huguette Guertin traveled to Chesnee, South Carolina, where she photographed with a 3.5-inch Maksutov with a 2x Barlow. The exposure was $\frac{1}{1000}$ second on EK 2483 transparency film.



expressed delight with the performance of his 7x Mylar-filtered binoculars. Fariss's young son, Mars Fariss, enjoyed both the binoculars and a large hand-held Mylar filter. Mick Rothery of Comer, Georgia, used a 10-inch reflector telescope to project a saucer-sized image of the eclipse onto a sheet of paper. Every four to five minutes he took photographs of the Moon's slow voyage across the disk of the Sun. Rothery mentioned that he owns three large telescopes, including a 17½-inch Dobsonian that he keeps in a home-built observatory.

When the cosmic curtain was finally pulled over the face of the Sun, exultant shouts rang out from the crowd of viewers. For nine seconds the Sun was all but blotted out, and the brilliant Bailey's Beads, caused by sunlight peeking through lunar mountains and valleys, performed a spinning dance on the projection plate of my 2.4 inch refractor.

The sky darkened noticeably, as it does during twilight, and the temperature dropped into the chilly range. Street lights blinked on, roosters began crowing, and the planet Venus was visible near the darkened face of the Sun. The eclipse resembled a Stygian-black tunnel into forever, its gaping entrance outlined by leaping tongues of orange fire. Then the drama was over as the Moon sailed on. "I'm ready for totality now," laughed one young man. "I just might head for Mexico in 1991."



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ANNOUNCEMENT — The Plutonian Society is looking for new members. If you are interested in astronomy, computers, or science fiction, the PLS is for you. Contact Kazys Varnelis III, P.O. Box 21, Stockbridge, MA 01262.

ANNOUNCEMENT — The Amateur Astronomers Association of Princeton will present slide shows, telescopes, photographs, and other exhibits at the Community Booth, Main Level, Quaker Bridge Mall, Rt. 1, Lawrenceville, New Jersey, on the weekend of September 22 and 23.

ANNOUNCEMENT — The Waterloo Amateur Astronomy Society has available astronomy programs for Atari and Timex-Sinclair computers. Included are Planet Finder and other useful programs. Contact W.A.A.S., 25 Bridgeport Rd. East, Waterloo, Ontario, Canada N2J 2J4.

ANNOUNCEMENT — The Pennsylvania Selenological society welcomes into membership any amateur astronomer especially interested in the astronomy of the Moon and its exploration. A semiannual journal, *Selenology*, is included with membership, which is only \$4 per year. Contact F. Graham, 417 Franklin St., East Pittsburgh, PA 15112.

ANNOUNCEMENT — The Raleigh Astronomy Club has scientific programs or observing sessions the second and fourth Friday of every month, meeting at 7:30 p.m. in Hunter Hall of Meredith College. Visitors welcome. Contact R.A.C., P.O. Box 10643, Raleigh, NC 27605 or phone Ward at (919) 787-5095.

ANNOUNCEMENT — **FOUND** — Nikon telephoto lens, during the May 30 annular eclipse at the Lake Hill Restaurant, Alexander City, Alabama. Contact Keith Hudson, 661 Shawnee St., Auburn, AL 36830. Phone (205) 821-9022.

ANNOUNCEMENT — Anyone interested in starting an astronomy club in the Redondo Beach, Torrance, and Palos Verdes area, please contact Mark Coco, 1120 Ysabel St., Redondo Beach, CA 90277.

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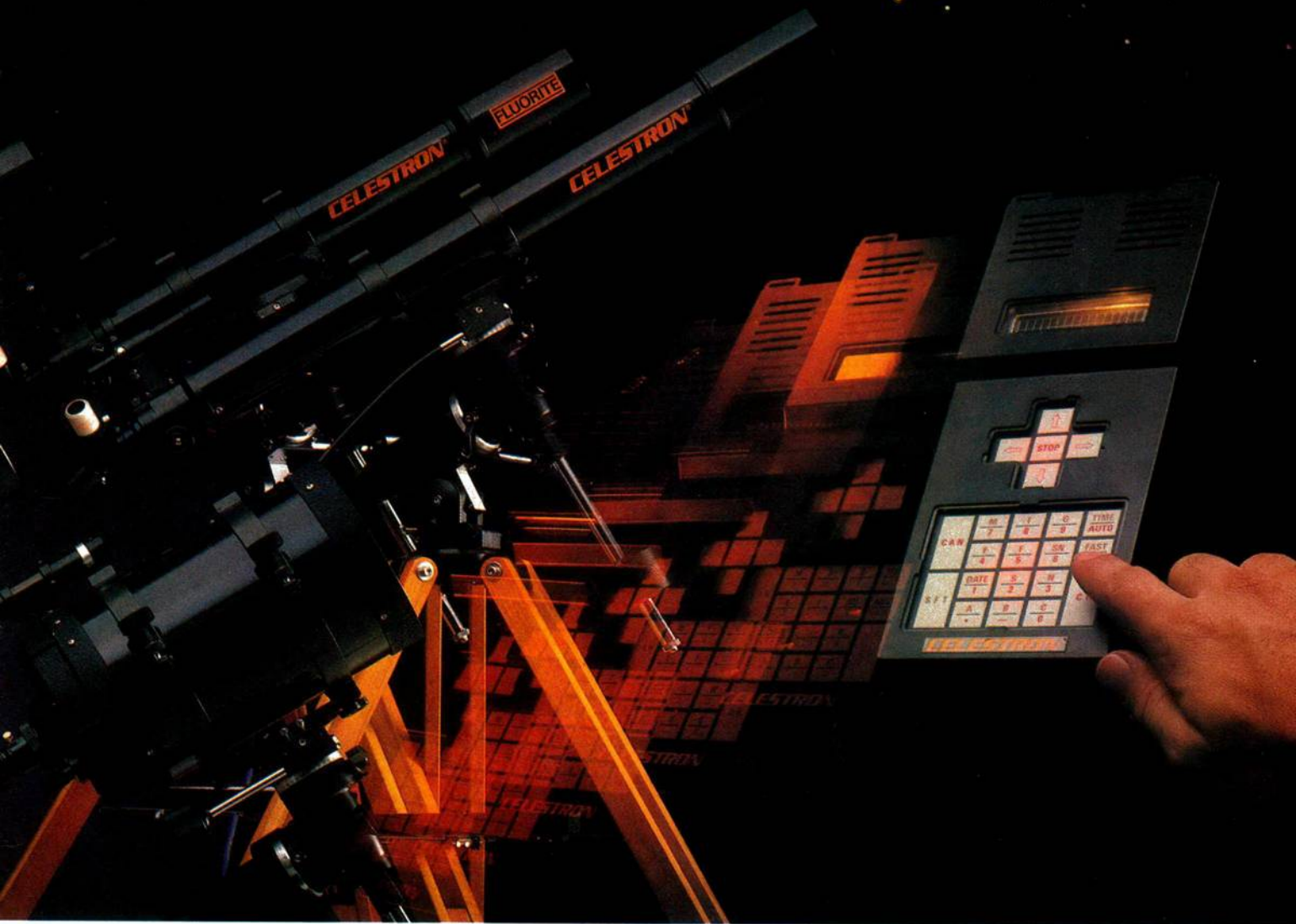
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Gaseous Shell Discovered Surrounding Nova Cygni 1975

Near the end of August, 1975, several groups of amateur and professional astronomers first spotted what became the most widely observed Milky Way nova to date — Nova Cygni 1975. The star rose from anonymity to slightly brighter than second magnitude, offering for a short time the chance to observe the nova process. During the months that followed, V1500 Cygni (as it was designated) gradually faded back out of range of even professional telescopes.

Nearly nine years later, on May 31, 1984, the University of Texas astronomer Gerard de Vaucouleurs made some photographic exposures of the area with the 82-inch Otto Struve telescope at McDonald Observatory. He discovered a tenuous expanding shell of fluorescing gas at the nova's site —

The gaseous nova remnant V1500 Cygni photographed at the Cassegrain focus of the 82-inch Struve reflector at McDonald Observatory by Gerard de Vaucouleurs. The fuzzy disk, glowing dimly at about magnitude 16.5, appears slightly larger than the stars surrounding it. The de Vaucouleurs plate is a 30-minute exposure on 103a-G spectroscopic emulsion.

the shell blown off by V1500 Cygni. De Vaucouleurs used a two-stage image intensifier at the f/13.6 Cassegrain focus of the instrument, allowing a very faint object to be recorded. According to de Vaucouleurs, the nebula measures 3.5×2.5 arc-seconds and, at the accepted distance of 1.4 kiloparsecs (4500 light-years), the shell's expansion rate of 0.2 arc-second per year since 1975 corresponds to a linear velocity of 1300 kilometers per second. These results are preliminary; de Vaucouleurs hopes to obtain more precise values during the coming months.

Arp 220: A Monster in the Sky

Scientists analyzing data from the Infrared Astronomical Satellite (IRAS) have found that a faint galaxy called Arp 220, some 300 million light years from Earth toward the constellation Serpens Caput, is one of the sky's brightest infrared sources. The galaxy emits as much energy as two trillion Suns, making it about 100 times more energetic than our own Galaxy, the Milky Way. Arp 220, also known as IC 4553, apparently consists of an extraordinarily bright central source surrounded by a vast dust cloud; the heating of this cloud by the nucleus produces the remarkable infrared emission.

Astronomers are mystified that such energy — comparable to that of quasars, the most energetic objects in the universe — could be generated. The IRAS scientists presented their discovery June 11, 1984, at the annual meeting of the American Astronomical Society in Baltimore. They are B. Thomas Soifer, George Helou, Carol J. Lonsdale, Gerry Neugebauer, Perry Hacking, and Walter Rice, all of Caltech, James R. Houck of Cornell University, Frank J. Low of the University of Arizona, and Michael Rowan-Robinson of Queen Mary College, London.

"These observations have actually created more problems than they've solved," said Soifer. "Before, we would have said that it was merely an interesting galaxy, but now that we appreciate how luminous it is, we have to explain a quasarlike luminosity that does not fit with conventional objects."

"If it were a quasar, it would be the closest quasar yet identified, and it is more luminous than a Seyfert galaxy." Seyfert galaxies, which provide a possible link between quasars and normal galaxies, emit unusually high amounts of radiation.

"There are galaxies that undergo extreme bursts of star formation due to the collapse of large dust clouds, and Arp 220 could be one of these starburst galaxies," said Soifer. "However, Arp 220 would represent an extreme example of this process and thus does not fit easily into that model."

"Other IRAS studies have found a number of infrared sources that have no observable optical counterpart in the Palomar Sky Survey. Arp 220 is so faint that if it were much farther away, it could not be detected visually either," said Soifer. "Thus, this galaxy may be a prototype of a kind of object that we did not know about before — one that emits 99 percent of its energy in the infrared. It may be a new member of the extragalactic zoo."

Indonesia to Build World's Largest Radio Telescope

A joint effort by UNESCO and scientists in several countries has begun a project to construct what will be the world's largest radio telescope, in Piobang, West Sumatra.

The telescope, to be known as the Giant Equatorial Radio Telescope (GERT), will have a 2-kilometer-long cylindrical antenna 50 meters across; the reflector surface will be a mesh

grid 3 centimeters on a side. Construction may begin as early as the spring, and the total cost will run to about \$20 million.

Vega's "Solar System" — Comets or Asteroids?

In the summer of 1983, the Infrared Astronomy Satellite (IRAS) discovered a shell of cool material around the star Vega. It subsequently detected similar shells around Fomalhaut and several other stars.

The shell around Vega lies at a distance from the star of about 85 AU and has a temperature of about 85° Kelvin. The IRAS scientists interpret the results as indicating that the material has a sub-centimeter size and could contain anywhere from a hundredth of an Earth mass to several hundred Earth masses.

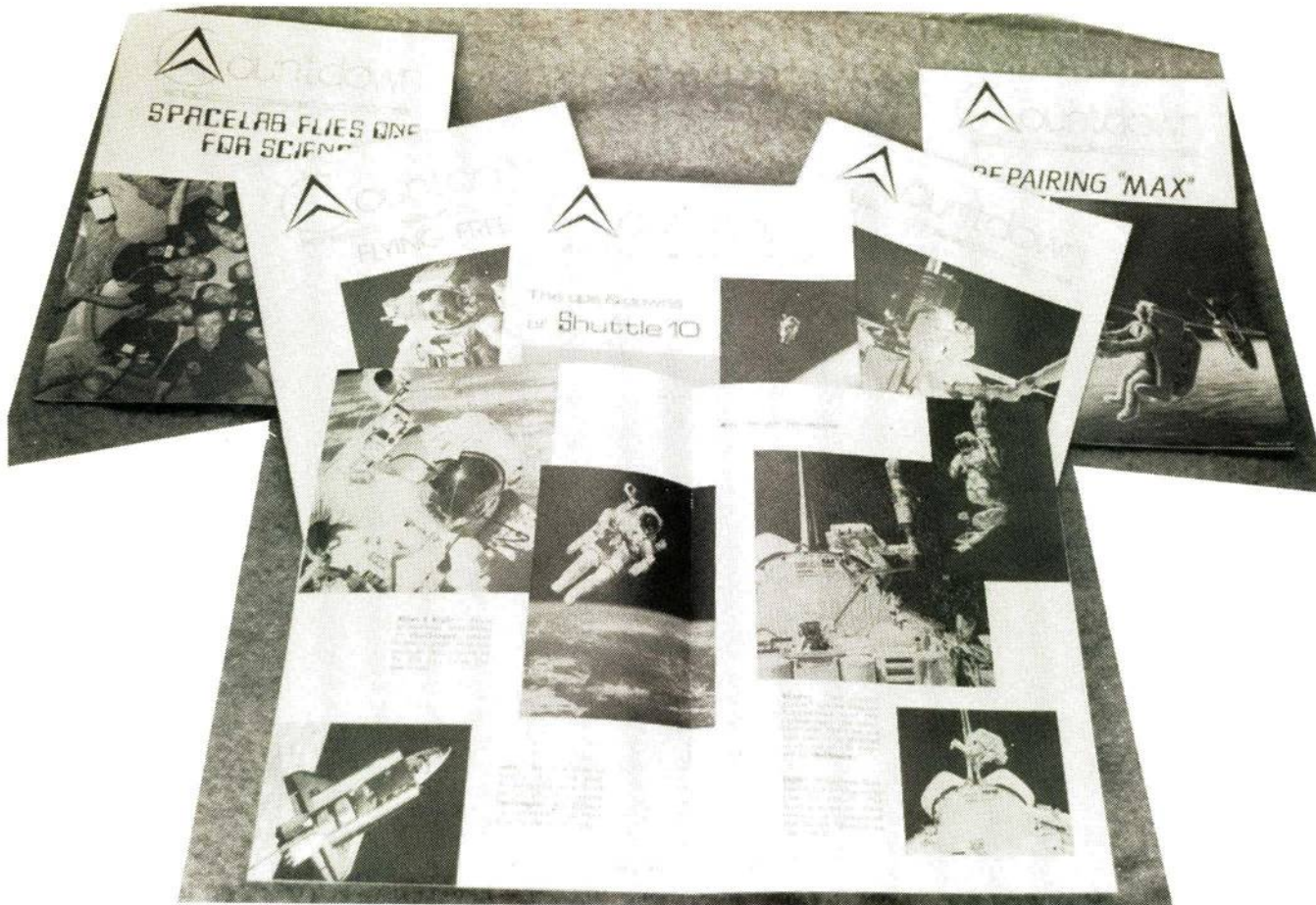
Paul Weissman, a researcher at the Jet Propulsion Laboratory, writing in a recent issue of *Science*, asks if this material is cometary or asteroidal in nature. He points out that at the material's temperature and distance from the star, the dominant fraction would be ices — primarily water ice.

But calculating the size of the particles depends heavily on a number of assumptions. IRAS was seeing only the smallest of the particles because these have the greatest amount of surface area relative to their mass and thus heat up fastest under the flux of starlight from Vega. Much larger pieces could be present also, but would be too cold to register. However, the slow orbital period for material 85 AU from Vega (554 years) keeps the collision-accretion process fairly weak, so large objects would probably be quite scarce.

After reviewing the evidence pro and con, Weissman concludes that, with suitable modifications, the current models for the early solar system offer the best guess for what we'd find at Vega: that the shell material is "very likely composed of cometary-like bodies with sizes ranging from asteroidal dimensions (100 to 1000 kilometers in diameter) down to particles tens of micrometers in diameter that are producing most of the thermal radiation observed by IRAS."

Planets? "It is improbable that the Vega ring contains planetary-sized bodies. The accretionary times for large bodies at this distance from Vega are too long because of the long orbital period and the short estimated age of the Vega system. [However,] this does not preclude the possible existence of planets





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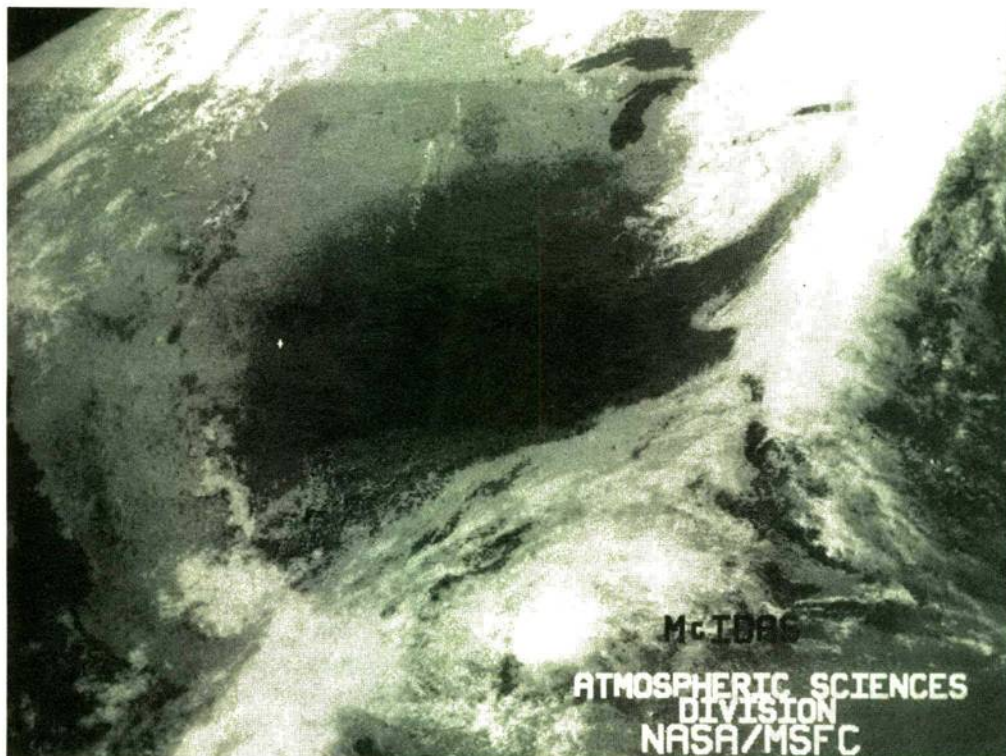
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The GOES-5 satellite viewed the southeastern U.S. on Eclipse Day, May 30th. Here the Moon's shadow passes New Orleans. (For more on the eclipse, see page 51.) NASA/Marshall Space Flight Center photo.

closer to Vega."

A tantalizing hint of the latter possibility comes from an infrared excess in IRAS' 12 micrometer spectral band. One interpretation of this excess is that there is material inside the 85 AU shell, and it could be as hot as 500° K. This would correspond to a collection of common, rocky type-S asteroids at a distance of 2.2 AU from Vega.

Europe Enters Remote Sensing Field

Lying somewhere on the hazy border between experimental science and tool, remote sensing satellites promise to become the third major business in space — after communications satellites and materials processing. Despite this, applications satellites are a relatively new activity in Europe. At present, aside from a lively communications satellite industry, only the Meteosat weather satellites in geosynchronous orbit are operational. A number of new satellites are, however, undergoing development, and J.N. de Villiers of the European Space Operations Centre recently described some of these in the European Space Agency's *Bulletin*.

Now scheduled for launch in 1988 is the Earth Resources Satellite-1. The main payload for

ERS-1 is a synthetic aperture radar similar to that used on the second Space Shuttle flight and on Seasat. Other instruments include a radar altimeter and laser retroreflectors for tracking. According to de Villiers, the planners intended to include an ocean color-monitoring instrument to measure the bio-productivity of the oceans, but this was later dropped and is now a prime candidate for a follow-up mission.

In addition to SPOT, a French Landsat-type project being prepared for a 1985 launch, the European Space Agency is studying a large second-generation Landsat. Because of Europe's often cloudy weather, this platform will include two imaging radars operating at different frequencies in order to see through clouds and assess water resources, including snow. Other sensors would include a stereo optical imager to observe in the visible and near-infrared, and an imaging microwave radiometer with a resolution of a few kilometers.

A second-generation Meteosat is also under study. Since the present spacecraft could be upgraded only modestly, an entirely new platform probably would be required. Instruments considered include an imager with one-kilometer resolution in the visible and near-infrared bands, and four kilometers in the thermal infrared, and a 14-channel

imaging microwave sounder that would measure temperature and water vapor at different levels within the atmosphere.

One of the most important issues facing scientists who would understand Earth's weather is our planet's radiation budget. Radiation is best measured by a number of sensors and from many different angles, since most climatology and atmosphere-related problems are global. Moreover, Earth's outgoing radiation varies with time, position on Earth's surface, wavelength, and angle with respect to the vertical. No single satellite can overcome all these problems — therefore, the Europeans will most likely place a number of host sensors on many meteorological satellites in geosynchronous and Sun-synchronous orbits.

Two other applications ESA would like to address are precise mapping of terrestrial gravitational fields and positional measurements of Earth's rotational parameters and tectonic plate motions. The latter requires a satellite with a very stable orbit, the exact shape of which must be well known. Such a satellite has to be small and dense to combat radiation pressure and atmospheric drag. Accordingly, ESA is proposing Popsat (for Precise Orbit Positioning Satellite), which might achieve accuracies of a few centimeters.

But Popsat's high orbit, designed to minimize gravitational perturbations which would disturb its position measurements, is thus unsuited to measuring gravitational anomalies, which require a low orbit. One promising way to measure these would be to place two satellites in the same orbit and observe the relative accelerations caused by the differing gravitational field their orbit takes them through. But this would depend on developing a satisfactory spaceborne laser system for measuring range and range-rate precisely in space — a technology unlikely to be available for flight before the 1990s.

Finally, de Villiers argues that "it is necessary to provide flight opportunities for instruments that are still at the experimental stage, seek to prove new concepts, need to be deployed on several satellites, [and] benefit from being recovered." These requirements may be fulfilled by Spacelab and by Europe's new retrievable carrier platform, Eureka. Donald F. Robertson.

It's Official: Impact at End of Cretaceous

Four years ago, Luis Alvarez and his co-workers reported finding anomalously large abundances of iridium in clays deposited at the geological boundary between the Cretaceous and the Tertiary periods — the same time when many species on Earth (including the dinosaurs) became extinct.

This finding, and their explanation that the iridium arrived in the form of an asteroid impact, provoked a lot of controversy. Field work has generally supported the idea, but the arguments in favor of the impact have been based ultimately on what amounts to an unusual condition: more iridium than anyone could easily account for, except by impact.

Now, four researchers at the U.S. Geological Survey in Denver (B.F. Bohor, E.E. Foord, P.J. Modreski, and D.M. Triplehorn) have published evidence in a recent issue of *Science* that makes the Alvarez impact hypothesis all but certain. Instead of looking for indirect clues such as element abundances, they concentrated on physical-mineralogical

ASTRO NEWS

gical studies of the material.

From a claystone layer, found in 1982 in Montana and deposited at the Cretaceous-Tertiary boundary, they extracted a sample that proved to have about 200 times more iridium than the local background material did. Placing this material in a scanning electron microscope, they observed several interesting and unusual features in it.

First, the claystone contained tiny spherical particles of kaolinite totally different in shape from similar samples found widely all over the Rockies. Second, when they dissolved the clay matrix and acid-etched the residue (overwhelmingly made up of quartz grains), they discovered that the grains had planar structure. This structure is not found

in other samples of quartz grains taken from elsewhere in the geological sequence, but it is similar to features found in highly shocked rock samples taken from known impact craters.

To rule out the possibility that the features were caused by terrestrial processes, the researchers measured the angles of deformation and found that some grains had as many as seven sets of planar features. (Grains with terrestrially generated planar features rarely have more than one set and, in addition, take on a different form.) Finally, X-ray diffraction analysis showed evidence that the quartz contained some stishovite, a type of quartz metamorphosed by high pressure and found only in impact craters.



My insurance company? Cretaceous Mutual, of course. Why do you ask?

ASTRO CALENDAR

August 24-26

Connecticut River Valley Astronomers' Conjunction, Northfield Mountain Center, Northfield, Massachusetts. Contact: Jack Megaw, 311 Surrey Rd., Springfield, MA 01118.

August 24-26

Starfest '84, Third Annual Observing Convention of the North York Astronomical Association, The River Place, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Toronto, Ontario, Canada M5R 2M1. Phone (416) 922-6294.

August 28-September 2

Eighth International Planetarium Directors Conference (professional meeting), Stuttgart, West Germany. Contact: Dr. Hans-Ulrich Keller, Director, Planetarium Stuttgart, Neckarstrasse 47, 7000 Stuttgart 1, West Germany.

September 2-6

International Union of Amateur Astronomers General Assembly, Bologna, Italy. Contact: IUAA, C.P. 1630 AD, 40100 Bologna, Italy.

September 21-23

Astrofest. Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477.

September 22

Ohio Turnpike Astronomers Association Convention, Akron, Ohio. Sponsored by the Astronomy Club of Akron. Contact: Philip Hegenderfer, 5070 Manchester Rd., Akron, OH 44319.

October 6

Astro Assembly, Seagrave Observatory, North Scituate, Rhode Island. Sponsored by Skyscrapers, Inc. Contact: Gerald Dyck, 418 High Hill, North Dartmouth, MA 02747.

October 9-12

16th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society (professional meeting), Kailua Kona, Hawaii. Contact: David Morrison, Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822.

October 11-14

17th Annual Pacific Region Aerospace Education Conference, Seattle, Washington. Contact: Julie Zumwalt, Director of Aerospace Education, Mather AFB, CA 95655. Phone (916) 364-4610.

October 13-16

Conference on the Origin of the Moon (professional meeting), Kona, Hawaii. Sponsored by the Lunar and Planetary Institute and the Division for Planetary Sciences of the American Astronomical Society. Contact: Pam Jones, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058. Phone (713) 486-2150.

October 19-21

Sixth Annual Custer Astronomy Club Jamboree, Southold, Long Island, New York. Contact: Warren E. Hamburger, President, 320 Asharoken Blvd., Bay Shore, NY 11706. Phone (516) 666-8654.

October 24-27

Great Lakes Planetarium Association Conference, Milwaukee, Wisconsin. Contact: Gary E. Sampson, Wauwatosa West High School Planetarium, 11400 West Center St., Milwaukee, WI 53222.

October 26-27

AAVSO Fall Meeting, Salem, Massachusetts. Contact: AAVSO, 187 Concord Ave., Cambridge, MA 02138. Phone (617) 354-0484.

January 13-16, 1985

Meeting of the American Astronomical Society (professional meeting), Tucson, Arizona. Contact: AAS, 1816 Jefferson Pl. N.W., Washington, DC 20036.

April 18-21

National Meeting of the National Science Teachers Association, Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington DC 20009.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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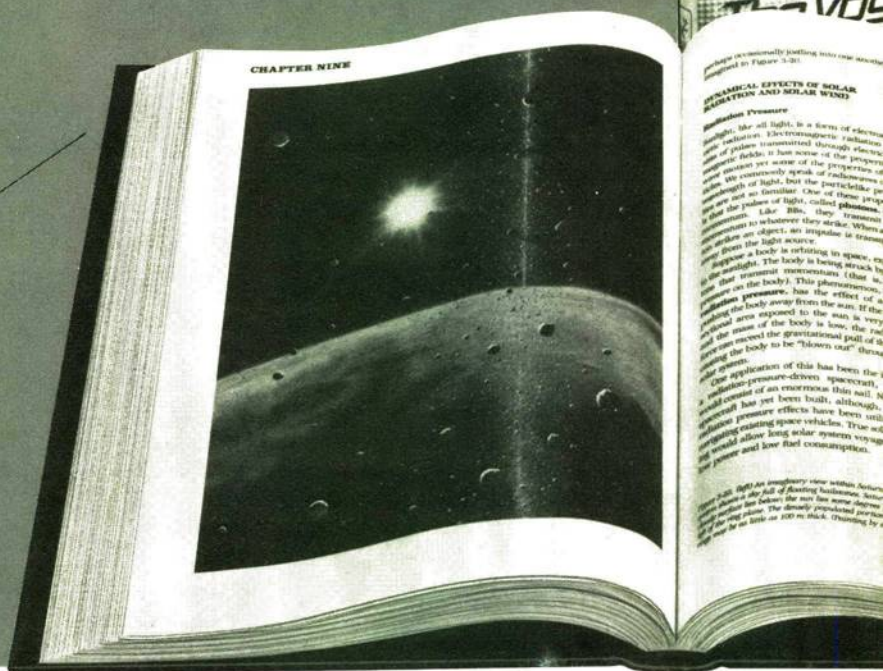
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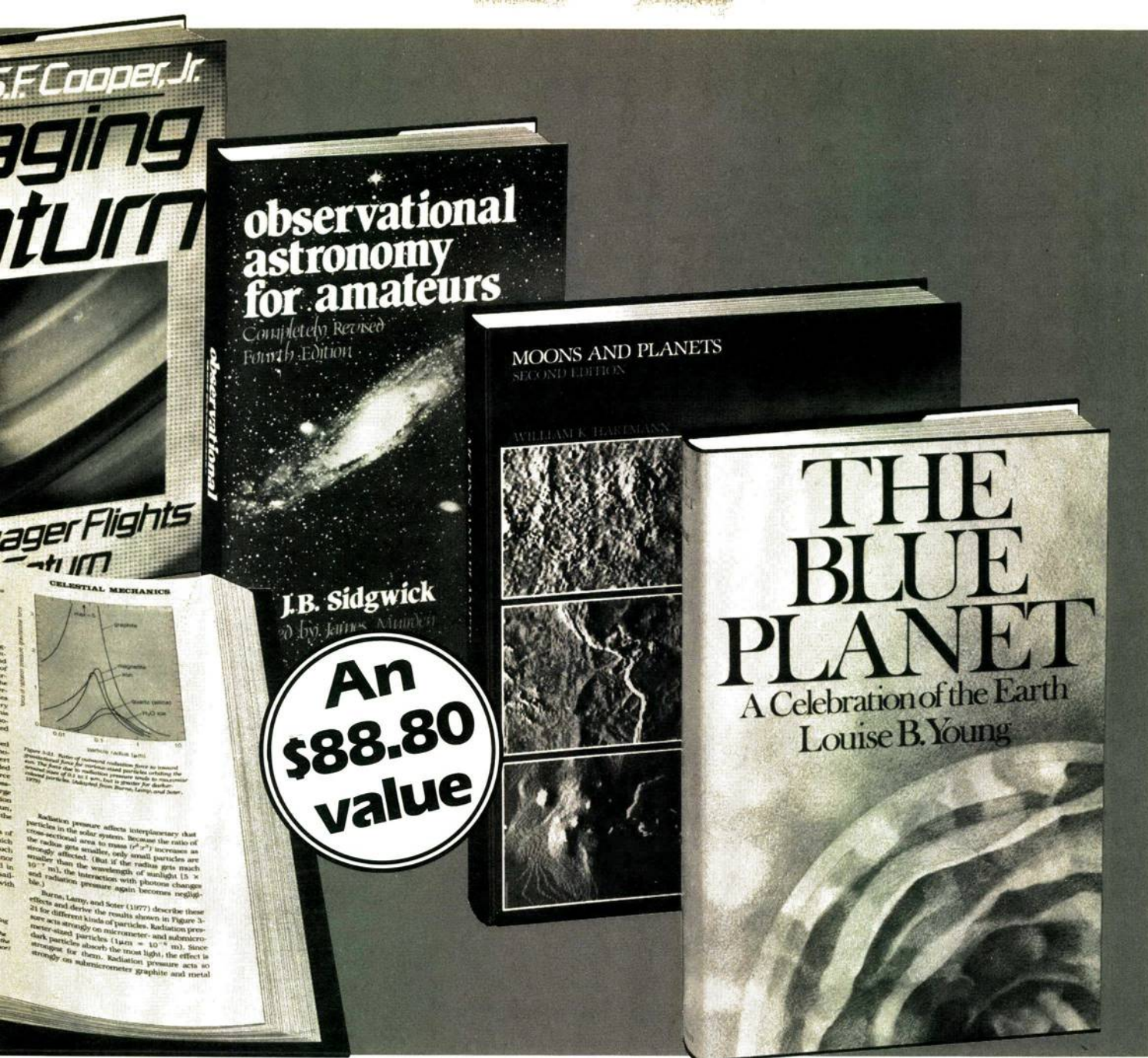
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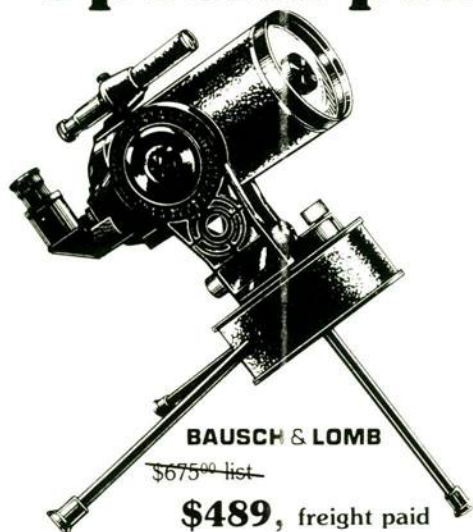


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AGAINST ALL ODDS: MATTER AND EVOLUTION IN THE UNIVERSE

by Wallace and Karen Tucker

Time, Henry Thoreau once said, "is but the stream I go a-fishing in." It is a stream that always flows in the same direction — aging begins from the moment of our birth and continues inexorably until death. This fate is not ours alone — all other life on Earth shares it. Even the stars, once thought to be unchangeable, evolve toward a death of sorts, burning out over the course of billions of years. "Nothing endures but change," wrote Heraclitus, and he was certainly right. The question is: Why?

The Second Law

Physicists tell us about the Second Law of Thermodynamics, which states that the entropy, or level of disorder, increases with every change in any closed system. This increase in entropy represents the energy that is no longer available for doing work in the system. Put more simply, the Second Law decrees that order must eventually turn into disorder. A hot cup of coffee cools as it diffuses energy into its surroundings. A well-ordered deck of cards becomes disordered when shuffled. Any collection of particles, any physical system, tends to move from organized states to disordered states. There are many ways to disorder a deck of cards, for example, but only a few ways to arrange them in an orderly fashion. If we drop a sugar cube into a glass of water, the cube slowly dissolves into a sugar-water solution. Although it is conceivable that the sugar in the solution might spontaneously condense back into a cube — a momentary reversal of the normal trend — the odds against it are so great that you'd have to wait longer than the life of the universe for one such event to occur! It is this tendency for things to become disorganized that defines the direction of time's irreversible flow.

How, then, did the systems around us become ordered in the first place? We can invoke outside influences in isolated instances. For example, we can say that a new deck of cards is perfectly ordered because a machine was instructed to print them that way. But as we examine larger and more complex systems, it becomes harder to invoke outside influences. Take, for instance, the most extreme case — the universe. It contains a rich variety of orderly structure, such as galaxies, stars, and planets. We can't invoke outside influences because the universe, by definition, includes everything. Yet the standard Big Bang model for the birth of the cosmos assumes that the universe began in a state of primeval chaos as a hot "soup" of elementary nuclear particles. At first glance, the cosmos seems to have become *more* ordered since the Big Bang — the reverse of the process decreed by the Second Law.

How can we resolve this seeming conflict between astrophysics and thermodynamics? For one thing, we

know that the universe is expanding.

The density and temperature of the early cosmos was so great that it remained in thermal equilibrium, the state of maximum disorder — that is, its temperature was uniform and there were no hot or cold spots. Elementary particles were born out of this uniform cosmic soup in proportions appropriate to the density and temperature. When the universe was one second old, approximately equal numbers of photons, electrons, and neutrinos coursed through it. Protons and neutrons were also present, but at a much lower concentration — about one in every billion particles. As the universe expanded and cooled, conditions favored different reactions between elementary particles. Protons and neutrons collided and joined in this cooler cosmos, forming the nuclei of atoms — first hydrogen, then helium, carbon, and silicon, as more protons joined the original nuclei. If these conditions had persisted, all of the nuclei in the universe would have built up to form iron, where the process would have ceased. Iron is the most stable nucleus, and to synthesize any heavier nuclei would take energy out of the expanding universe.

But this never actually happened. Long before the process could run to completion, the universe had expanded and cooled to a point where conditions favored other processes. Freeman Dyson of Princeton University's Institute for Advanced Study calls this "the thermonuclear hangup." What stalled the rush toward a static, inert, iron-filled universe? The relatively slow thermonuclear processes required to transform protons — hydrogen nuclei — into heavier, more stable nuclei gave the universe time to cool off before the reactions could run their course. As a result of this hangup, most of the matter in the universe wound up as hydrogen — plus some helium and a bit of lithium that were synthesized just under the wire. Today, the nuclear



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reactions in stars transform this hydrogen into heavier nuclei. Thus stars are really a sort of cosmic governor, a mechanism attempting, however slowly, to restore the universal equilibrium lost a fraction of a second after the Big Bang.

The Clumpiness Problem

The distribution of matter displays a clear tendency to grow clumpy as time progresses. It clumps into galaxies, stars, planets — even black holes, if possible. This tendency toward clumpiness is the gravitational counterpart of the Second Law of Thermodynamics. Some theorists refer to this as “gravitational entropy,” meaning that, like thermal entropy, clumpiness due to gravity increases with time. The tendency for matter to clump together defines an “arrow of time” as surely as the tendency toward thermal equilibrium. It also implies that the gravitational field of the universe was once very smooth — that is, matter was smoothly distributed. A study of the large-scale structure of the universe suggests that the distribution of matter in the primeval universe was exceptionally uniform. Yet paradoxically, analysis of the dynamics of the early universe indicates that a highly turbulent, irregular universe full of black holes would have been far more likely than the featureless fluid from which the known universe apparently evolved. How did the universe manage to get into such an unlikely state, peppered with such complex and highly-ordered structures as superclusters of galaxies and life?

Recently, Paul Davies of the University of Newcastle suggested that some of these difficulties can be resolved by examining a new version of the Big Bang scenario —

the “inflationary universe.” The model incorporates recent developments in the physical theory of elementary particles into the early evolution of the universe. (See “The Decay of the False Vacuum,” *ASTRONOMY*, November 1983, and “The Planck Era,” March 1984.) According to the inflationary model, the universe went through a very brief (a few octillionths of a picosecond long) but extremely rapid phase of expansion — an event that liberated a tremendous amount of thermal energy and inaugurated the milder cosmic expansion we now observe. During this brief but critical phase of exponential expansion, Davies argues, any clumpy distribution of matter was smoothed out long before the clumps could collapse into black holes. The observations that imply a uniform distribution of matter in the early universe are not puzzling, contends Davies. On the contrary, with an inflationary universe, it is difficult to imagine how matter could have been distributed in any



other way.

Once the phase of rapid expansion ended, matter could start down a new path — one in which it clumped together into increasingly more compact objects: galaxies, stars, and black holes. The evolution toward gravitational and thermal equilibrium is going on today, and accounts for most of the structure we now see in the universe. And this is all perfectly natural, just the way you'd expect things to happen, right?

Not necessarily, says Don Page of Pennsylvania State University. He argues that Davies has made a classic debating error — that of begging the question. According to Page, Davies has presupposed the conclusion to his argument. It is natural to assume that the matter in the universe will be smoothed out because of extremely rapid expansion, Page admits, but it is only natural because that is how we see nature behave. Yet this is also precisely what we are trying to explain — why

nature behaves this way and not some other way. We have, in effect, merely pushed our ignorance back another step. If we want to prove that the universe was smoothed out by an inflationary phase, then we must first prove that the likelihood of growing a universe from a very small volume is greater than that of forming one directly from a large volume. In addition, we must show that such a universe would indeed smooth out through expansion and not collapse into numerous black holes. Both conjectures are eminently plausible, and neither has been proven right. And until that happens, we cannot determine whether the inflationary model creates the most likely cosmos, or merely one of a multitude of possible but unlikely universes.

So the reason why the universe got out of gravitational equilibrium remains a mystery still. And until we understand that, we will not have a satisfactory explanation for the direction of time's flow. On the other hand, we are now in a better position to understand another, seemingly paradoxical, aspect of the universe — it seems to be evolving in the direction of increasing complexity, from an undifferentiated soup of elementary particles, to atoms, molecules, and life. There has been



a clear trend in which complex states replace simpler ones. David Layzer, a cosmologist at Harvard University, calls this trend the "historical" arrow of time.

The Rules of the Game

How is it possible to have a universe that is both running down thermally *and* becoming more organized at the same time? To resolve this paradox, we must turn to the laws and constraints that govern the evolution of the universe. The laws, such as the law of gravitation, define what is possible; the constraints, such as the initial conditions of the Big Bang, define what is actual or relevant. For example, the law of gravitation says that a trapeze artist will fall to the Earth upon letting go of the trapeze. But other constraints, such as the presence of a safety net or of a partner within catching distance, can provide a "hangup" that prevents the obvious result. Similarly, cosmic constraints like the thermonuclear hangup prevent the universe from running down immediately into a state of maximum entropy.

This is the point of view usually taken by cosmologists when they try to explain why the universe has taken so long to die the "heat death" implied by the Second Law of Thermodynamics. Going back to our card-shuffling analogy, these hangups take the form of delays in the rate at which the cards are shuffled. Other scientists, most notably Layzer and Ilya Prigogine of the Free University of Brussels, argue that this line of reasoning gets us nowhere in trying to understand cosmic evolution and the historical arrow of time. It's not just that constraints slow the rate of card shuffling — they actually introduce order into the arrangement. This

happens in many card games. In bridge or hearts, for example, a constraint of play introduces order into the distribution of cards. Players must follow suit if possible — that is, if a spade is played, then they must play a spade, etc. This constraint leads to concentrations of cards of a particular suit. Repeated shuffling before the next deal can destroy these concentrations, but some order will remain if the shuffling is inadequate. In fact, one of the primary cheating techniques of a professional card shark is simply inadequate shuffling.

Is nature playing similar games? Are there universal "playing rules" that lead to order rather than disorder? According to Prigogine, the answer is yes. He points to a class of chemical processes known as Belousov-Zhabotinsky reactions. Here, one of the reaction byproducts actually makes it easier for the processes to occur. Remarkably, these reactions display a self-organizing property — large, stable spiral- and ring-shaped structures appear spontaneously. While investigating a shock-wave model for the formation of the galactic spiral arms, astronomers Barry Madore and Wendy Freeman of the University of Toronto developed computer simulations that reproduce the characteristics of these self-organizing chemical reactions. In their model, a massive star undergoes a supernova explosion. This explosion drives shock waves through interstellar space, and these shock waves precipitate the formation of other massive stars. The most massive of these new stars will eventually explode themselves, producing shock waves that will form still more stars. The result is a chain reaction of supernova explosions that can, under a wide variety of conditions, create spiral structures similar to those observed in many galaxies (see "To Sculpt the Galaxies," *ASTRONOMY*, January 1983). On further investigation, Madore and Freedman found that the shock-driven model of spiral arms was just a special case of a broad class of reactions that lead to large self-organizing structures. Included in this broad class, they believe, are the Belousov-Zhabotinsky chemical reactions, the growth patterns of slime molds, and certain stages of embryonic development.

We can understand the historical arrow of time — the trend toward increasing complexity in the universe — in terms of the interplay between various constraints, which work to slow down the disordering process, and self-organizing reactions, which can take place once entropy has been slowed. What about the long-term prospects for our universe? Is it doomed to the death so long discussed by gloomy cosmologists? Not necessarily. As the universe expands, argues Layzer, its theoretical maximum entropy increases. Our universe tries to achieve this theoretical maximum, but various hangups get in the way, keeping the universe from reaching its lowest energy state. As the universe evolves, the gap between its actual entropy and the maximum possible entropy grows ever wider. We perceive this widening gap as the increasingly complex structures that inhabit the universe — we see it in the historical arrow of time. As David Layzer puts it, "The universe is unfolding in time but not unraveling; on the contrary, it is becoming constantly more complex and richer in information."

Wallace Tucker is an astrophysicist associated with the Harvard-Smithsonian Center for Astrophysics and the University of California at Irvine. Karen Tucker is a freelance science writer.

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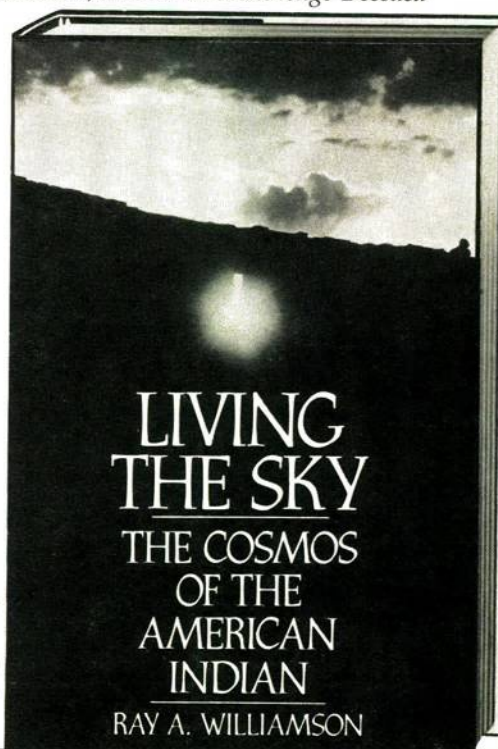
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LIVING
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Building an Equatorial Tracker for Astrophotography

by
Daniel Hatch

You know, the only *real* problem in astrophotography is that your subject won't stay put! Get this one problem licked and all the rest reduces to "mere details." But it's inescapable — every minute of every day, the Earth steadily rotates: 360° every 24 hours, 15° an hour, 15' of arc every minute. If your time exposures of the sky are to come out unstreaked, you have to counteract this movement.

Enter the equatorial mounting. By putting one of its two axes parallel to the rotation axis of the Earth, a single simple motion lets it track any celestial object for as long as you like. Over the years many types of equatorial mounting have been devised, and all are suitable for photography — at least in principle. But the problem with most of these is that they are complex in design, difficult to construct, or expensive to buy or make.

But don't give up hope just yet — from *Down Under* comes a design for a mounting that is simple and ingenious. The "equatorial box" is the brainchild of Australian amateur astronomer Graeme White, and its greatest advantage is the ease with which you can build it. (See *Telescope Making* #14, p. 17.)

In essence it is a box that is cut in two in such a way that the cut line runs at an angle equal to your latitude. The box is hinged to open or close along that line. With the base leveled and the hinge pointing at the pole, you can then open or close the upper part of the box at the proper sidereal rate — and any camera riding on top will follow the stars.

Of course, it's not *quite* that simple. There are a few tricks to building the box, and a few more to using it to best effect — but more on that later. The materials you need are easily obtained from your local hardware or building supply store and will probably cost less than \$30. (See the list of tools and materials on the opposite page.)

Begin constructing the box with the most important part — the hinged side. This is one of the few critical sections

where you can't afford to be sloppy.

On one end of the pine plank, trace the bottom section of the hinge board (see diagram), making angle A equal to your latitude. Since this angle has to be precise, I recommend you use a large protractor or trigonometry to avoid error. Square off the section with a right angle and cut the piece out. Be sure to choose a flat, straight piece of wood and pick the straighter edge for your base.

Now repeat the procedure for the top section and fit the two pieces together. If you've done the job right, top and bottom hinge boards should fit together perfectly. If they don't meet exactly, recheck your measurements on the bottom board and plane down the edge until it is straight.

At this point, you have to decide if the box will open or close as it tracks. I chose to make a "closer" so the tracking platform slowly lowers under the force of gravity; this seems to make for smoother tracking. This is the version described hereafter. Turn the taller (north) end of the bottom hinge board toward you; you are now facing "south," and the stars will move from left to right with the top of the box going down as you track. The hinges therefore should go on the right-hand side (inside the box). Mark the inside and outside of the boards before you go any further to avoid confusion.

Now notice how the top and bottom pieces butt together tightly. In order to allow the box to move easily, you'll have to plane a bevel on the outside of the joint to provide clearance. Bevel both hinge boards, but take real care with the bottom one, where the tolerances are critical. Or if you like, plan to leave a half-inch gap between the halves when you mount the hinges.

You are now ready to put the hinges on — a step requiring care and precision. Once again, you want the bottom hinge board to be as close to perfect as you can get, so carefully align the hinges parallel to the joint, leaving clearance for the pins. Make sure that the hinge pins line up with each other — this is your mount's polar

axis, remember — and take special pains when screwing the hinges down.

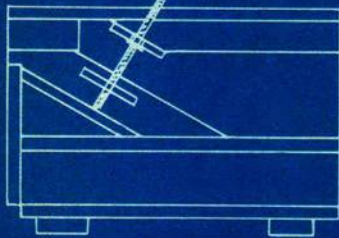
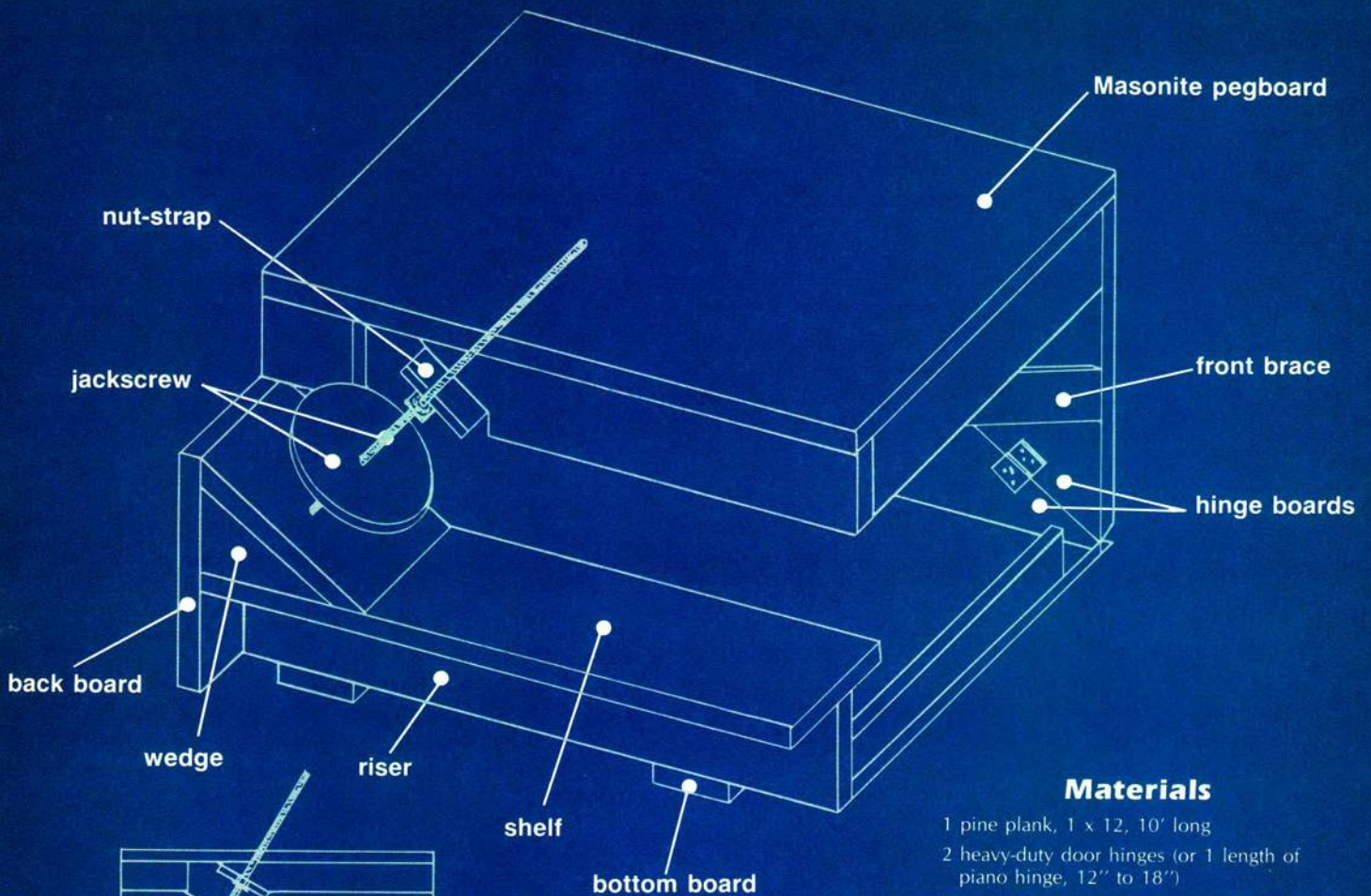
There's always some chance the screws will creep and skew the hinge. If the movement is very small, you can probably get away with it — but don't be afraid to move the hinge a half inch and try again. When you attach the hinges to the top board, you can ease up on the tolerances: so long as the hinges on the bottom board are lined up correctly, the box will still rotate around the proper axis. (This is where you might wish to try a length of piano hinge — it will simplify the alignment problem.)

Before you attach the top hinge board, finish off the base of the box. While the back of the box is not too important, the end opposite the hinge — the "west" end — is. To make sure the axis of rotation actually points at the pole star, you must insure that the bottom hinge board stands vertical relative to the base.

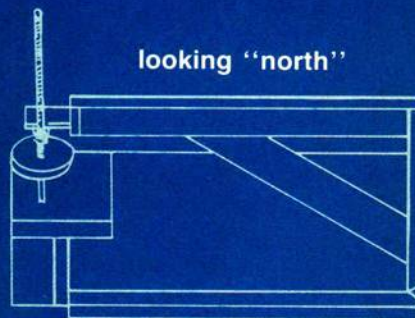
First, attach the back of the box to the north end of the bottom hinge board with glue and screws. The back need not extend the full height — in fact, making it low saves some weight and provides clearance. Then set the assembly on a flat surface. Use an L-square to check that the bottom hinge board stands vertically upright — shave or shim the back board as necessary. Then attach the "west" end of the base, again making sure the whole thing sits flat and doesn't wobble. Put a piece of furring strip across the front and, finally, attach the bottom boards. The bottom half of the box is now complete.

The top of the box goes somewhat easier. Build a frame of furring strips, cut the pegboard to fit, and put the two together with glue and screws. Make the "east-west" dimension of the top 23". (You'll see why in a minute.) Attach the top frame and pegboard to the upper hinge board with long woodscrews and glue — make that joint *solid* — and add support braces to insure stability.

The next part is the jackscrew that controls the tracking. The work here doesn't have to be precise, but there are



looking "east"

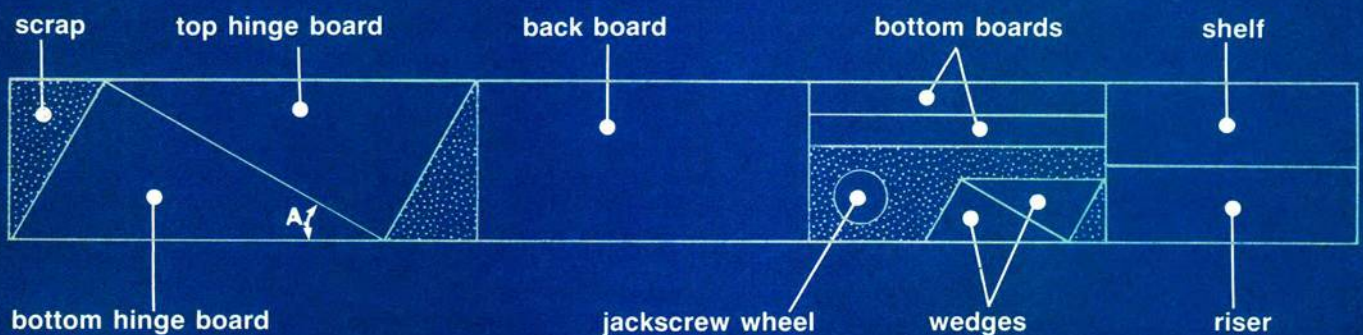


looking "north"

bevel

Materials

- 1 pine plank, 1 x 12, 10' long
- 2 heavy-duty door hinges (or 1 length of piano hinge, 12" to 18")
- 1 furring strip, 1 x 2, 8' long (get four times this if you are making the tracker's stand also)
- 1 sheet of Masonite pegboard, 2' square
- 2 perforated steel mending straps, 4" long
- 1 # $\frac{1}{16}$ -18 threaded rod, 3' long
- 1 # $\frac{1}{16}$ -18 nut
- 4 # $\frac{1}{4}$ -20 tee-nuts
- 4 # $\frac{1}{4}$ -20 bolts, 3" long
- assorted wood screws
- wood glue
- hammer, saw, screwdriver, drill, woodplane



some tricks to the design and construction.

First, you'll have to have some welding done at your local garage or auto-body shop. Weld a # $\frac{5}{16}$ -18 nut over one hole at the end of one of the steel mending straps. And weld the # $\frac{5}{16}$ -18 threaded rod to the other strap at a distance of about 8" from one end of the rod, with the rod passing through one of the inner holes on the strap. The strap with the nut on it goes onto the top of the box, while the strap welded to the rod will provide a secure attachment for a wooden hand wheel; the wheel, about 6" in diameter, must now be cut out and attached to the rod.

Connecting the upper steel strap (the "nut-strap") to the top of the box requires a little woodworking skill, but if you've gotten this far, you'll probably have no problem. Ideally, you want the threaded rod to run perpendicular to the hinge axis, but the exact angle isn't critical.

Cut a notch in the bottom of the box top, but don't attach the nut-strap yet. (You may need to beef up the place where it

goes with scrap wood to make a solid joint.) Then cut out the angled piece and fit it to the box bottom. In it drill a loose footing for the rod, about $\frac{1}{8}$ " deep; if the threaded rod just turns freely, everything's fine.

Now for the final problem in construction: just how far from the hinge do you place the threaded rod-and-wheel (the "jackscrew") and the nut-strap?

With a 35mm camera, a typical 50mm lens, and fast film, the normal resolution is around 80 lines per millimeter or so. This equals an angular resolution of about 1' of arc. Therefore, if you can keep your tracking errors to within 1 arc-minute, all the light from each star in your photo will fall within the resolution limit of the film and the star images will appear perfect. It takes a star four seconds to move 1 arc-minute. This means you'll have to rotate the box around the hinge at an angular velocity of 1 arc-minute every four seconds to produce perfect astrophotos with a 50mm lens.

Properly built and carefully aligned on the pole, simple astrophotographic trackers can produce splendid constellation photos. Ron Zullo used a simple "door hinge" tracking mount for this photo of Orion, taken with a 100 mm lens at f/2.8, High-Speed Ektachrome (ISO 200), and a 10-minute exposure.

The distance from the hinge to the nut-strap is the radius of your turning circle. How big should it be? For an 18-thread-per-inch rod, and with a hand wheel divided into eight equal sectors with finishing nails, turning the wheel one "nail space" every four seconds will produce the correct rotation rate around the hinge when the radius is 23.87". Position the nut-strap correctly by measuring carefully from the center of the hinge to the center of the nut, and attach it firmly in place. Then thread the rod through the nut and seat the lower end of the rod into its footing on the base.

At this point, the basic mount is ready — though I suggest you add some refinements. A bubble level will help you set up, and four tee-nuts with bolts projecting through the bottom boards of the box will provide adjustable feet. In addition, one of those ball-joint camera mounts that locks at any angle will make aiming easier.

You may have noticed that in order to operate the box, you either have to lie down on the ground beside it or build a stand to set it on. I wasn't keen to lie on the ground so I constructed a stand to raise the mount. Why not build the tracker high enough to eliminate the problem? Essentially, the two-part design makes the thing a lot more portable — throw one piece in the trunk, the other in the back seat, and you're ready to head for the hills.

My stand is a simple open frame made of firring strips (use lots of diagonal bracing!), but you could also make a box out of plywood that would serve as well, though it would be a good deal heavier. I discovered it helps a lot if you set up on a hard surface like a parking lot or tennis court — though shims under the legs of the stand would help with a hopelessly uneven surface.

Polar alignment is fairly simple — just sight along the hinge joint at Polaris. If you can see the pole star through the crack in the joint, you'll get good pictures. The mount will let you track along enough for most star field photos — up to half an hour, say. Run them longer than that and you'll begin to come up against the fact that the drive isn't exactly on the sidereal rate — but the sheer tedium of turning the wheel would probably keep you to short exposures anyhow!

In the end, I think you'll find the hassles of making the tracker are worth it. There is only one thing in the world more beautiful and breathtaking than a fine astrophoto — and that's a fine astrophoto that you've made yourself with equipment you've built by hand!

An Even Simpler Tracker

Designed by Scotsman G.Y. Haig about 10 years ago, this tracker is even simpler than the box mount. The model shown here was made by Roger Qualls, a friend of mine.

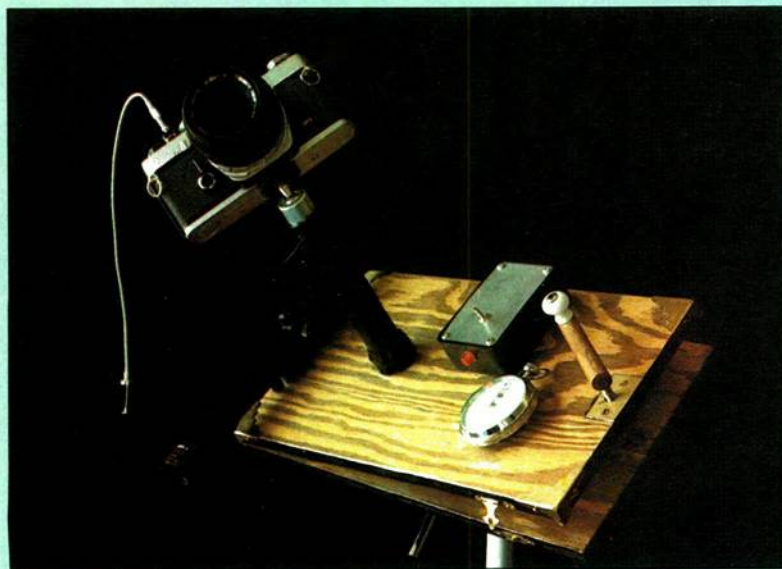
The body of the tracker consists of two boards hinged together like a book. The screw is a $\frac{1}{4}$ -20 bolt with a crank handle located 11.46" (11 $\frac{1}{2}$ " works fine) from the hinges. One turn per minute opens or closes the boards at the sidereal rate. You attach a (non-digital!) watch next to the crank handle so you can turn the handle in sync with the sweep-second hand on the watch.

On this tracker, a small red light illuminates the watch, but a flashlight would suffice. The ball joint that allows the camera to be pointed toward different

areas of the sky is a \$10 K-Mart item called a "Handipod." The riflescope, used for alignment on Polaris, was also purchased at a local store for \$10. Although not really necessary, the riflescope facilitates setting up — without it, you would sight along the hinges. This model rides on a photo tripod (for the latitude adjustment), but you could easily make an angled stand to sit on a flat surface.

The total cost of the tracker need not exceed \$25 to \$30. However, you can trim the cost to just about nothing if you omit the sighting scope and the ball joint. To replace the ball joint, take a piece of steel strap, perhaps 1 $\frac{1}{2}$ " x 8", bend it in a right angle about 2" from one end, and drill a $\frac{1}{4}$ " hole near each end. Fasten the camera to the long side and bolt the short side to the board — the camera can then be swiveled in two axes.

— George Briggs







Above: With the naked eye, the North America Nebula is easy to see, appearing as a large fuzzy patch, but its light is so spread out that it is difficult to detect with a telescope. Photo by Joseph Glowicki and Andrew Toth. Above right: One of the least flashy Messier objects, M-29 is nevertheless a bright, compact cluster composed of ninth magnitude and fainter stars. Photo by Lee C. Coombs. Right: The eastern half of the Veil Nebula is NGC-6992/5, which is visible as a ghostly arc in 8-inch scopes. Photo by Jack Newton. Below right: M-27, the Dumbbell Nebula, is one of the most impressive of the planetary nebulae. Photo by Ben Mayer. Below: The region of Gamma (γ) Cygni is filled with the huge emission nebula IC 1318. Photo by Al Lilge.



Cygnus

Cyg
Cygni

Vulpecula

Vul
Vulpeculae

Among groupings of stars in the northern Milky Way, the constellation **Cygnus** the Swan is the richest, as it contains multitudes of bright, young open star clusters, patchy regions of dark nebulae, wispy, elusive emission and reflection nebulosity, many planetary nebulae, and a handful of double and variable stars. The small constellation **Vulpecula**, the Little Fox, adjacent to Cygnus, also has a worthwhile telescopic target among its dim stars.

One of the brightest objects in Cygnus is the large, scattered open cluster **M-39** (NGC-7092). This group contains at least 28 stars, the brightest of which shine at seventh magnitude, in a diameter approximately half that of the Moon, resulting in a total magnitude of 4.6. This makes M-39 one of the finest large open clusters for binocular users, as most telescopic fields of view do not contain the entire group. The cluster lies about 245 parsecs distant, and has a linear diameter of 2.2 pc. The other Messier object in Cygnus is another cluster, **M-29** (NGC-6913). This little group of 81 stars of ninth magnitude and fainter is contained — in stark contrast to M-39 — in a diameter of only 7'. The combined magnitude of M-29 is 6.6, so it is easily visible in finder scopes, but it is not impressive as open clusters go.

More enthralling but much harder to observe is the complex of nebulosity surrounding the M-29 area and centered on the bright star Gamma (γ) Cygni, or Sadr. **IC 1318**, a vast region of emission nebulosity, is excited by young, hot blue-white stars and separated by dark nebulae into five major parts. The total magnitude of this nebulosity is probably fairly high, but its light is spread out enough to make small parts of it dim. Under pitch black

skies, a 5-inch RFT will show the wispy outlines of this large nebulosity. Embedded within the IC 1318 complex, on the northeastern side of γ Cyg, is the fine open cluster **NGC-6910**. This group consists of 66 stars of 10th magnitude and fainter in an area spanning 8', with a combined magnitude of 7.4.

Southwest of the γ Cyg region lie a number of unusual objects, one of which is the faint supernova remnant **NGC-6888**. This is a young shell of ionized gas that expanded outward from a hot central Wolf-Rayet star. Since it is one of only a handful of observable supernova remnants, it is a worthwhile target on nights of excellent transparency. Its surface brightness is extremely low — something like 14 — so you'll need either a very transparent night or large optics coupled with a red-transmitting nebular filter. Measuring 18' x 12', the nebula is visible in large binoculars under superb skies.

The open cluster **NGC-6871** lies in the "downtown" section of the Cygnus Milky Way — an area strewn with star clouds and cluttered with thousands of stellar images. The group stands out enough to be an obvious binocular target, however, because it measures 40' across, contains 66 stars of seventh magnitude and fainter, and shines with the light of a magnitude 5.2 star.

Also abundant in unique objects is the area around Deneb (Alpha [α] Cygni). One

of the most sought-after low-surface-brightness objects is the **North America Nebula**, NGC-7000. This giant emission region measures 120' x 100'; under dark skies, it is visible as a large hazy patch of light just southeast of Deneb. The integrated magnitude of NGC-7000 is perhaps 4.5, but it is so large that in the telescope little bits of it appear as 13th magnitude nebulosities; a 17.5-inch with nebular filter easily shows its outlines, but it fills several fields of view. Once again, you'll find binoculars often provide the best view. Due west of NGC-7000, separated by a broad band of dust, is the even more elusive **Pelican Nebula** (IC 5067-70). This is a part of the same region, measures 80' across, and has a surface brightness of something like 14. Faintly visible with large binoculars or RFTs, it becomes harder to pick out with large telescopes.

NGC-7027 is a strange object near the North America Nebula. It was originally believed to be a star, then a planetary nebula, and now it appears to be a bizarre emission object showing a complex spectrum. It measures only 18" x 11" across and has a photographic magnitude of 10.4, so it isn't always easy to pick out of a rich starfield at low power. It displays a slight blue-green color, so use medium power and look for a colorful "star" whose disk exceeds in size the stars that surround it. Also nearby are two

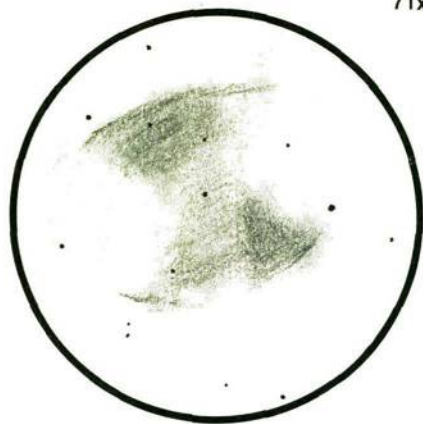


Keith Ward

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

M-27

17.5-inch f/4.5
reflector
71x



Sketch by David J. Eicher

planetaries: **NGC-7026**, a 12th magnitude object measuring 28" x 13", and **NGC-7048**, an 11th magnitude planetary whose disk spans 60" x 50" of sky. NGC-7026 can be difficult to find, but NGC-7048 is easily spotted within the low-power field of any small telescope.

Two more planetaries in Cygnus are **NGC-6826** and **NGC-7008**. NGC-6826 shines at ninth magnitude and measures 27" x 24". It is often called the Blinking Planetary, as it displays a curious effect that neatly demonstrates the technique of averted vision. After you find 6826 using averted vision, center it in the field and look directly at it. The nebula will fade,

leaving only the pinpoint 11th magnitude central star. Look to the edge of the field, and the nebula reappears. If you switch rapidly back and forth between averted and direct vision, the nebula appears to blink on and off. NGC-7008 is large but faint, measuring over one arc-minute in diameter but glowing dimly at 13th magnitude. Telescopes 10 inches in aperture may show it as a large fuzzy glow, devoid of detail.

The third and final grand complex of nebulosity in Cygnus is the sky's brightest supernova remnant, the **Veil Nebula**. Consisting of more than four distinct bright units of nebulosity, each of which has a separate NGC number, the Veil Nebula is the result of a supernova explosion that occurred some 30,000 years ago, about 450 pc away toward the Cygnus Arm of the Galaxy. The brightest section, designated NGC-6992 and NGC-6995, comprises the eastern half of the main loop, and is visible as a ghostly arc in an 8-inch telescope at low power. Its angular extent is 78' x 8', so it appears as a long, thin twisting spike, cutting through an entire field of view. NGC-6960, the western half, is easier to locate because it passes through the bright star 52 Cygni — a star that makes spotting the nebulosity harder than it should be. NGC-6960 is nonetheless visible in a 6-inch scope, especially with a nebular filter. NGC-6979, the central part of the Veil, is markedly fainter than the two main halves. A large telescope is capable of showing sharply defined, intricate detail throughout

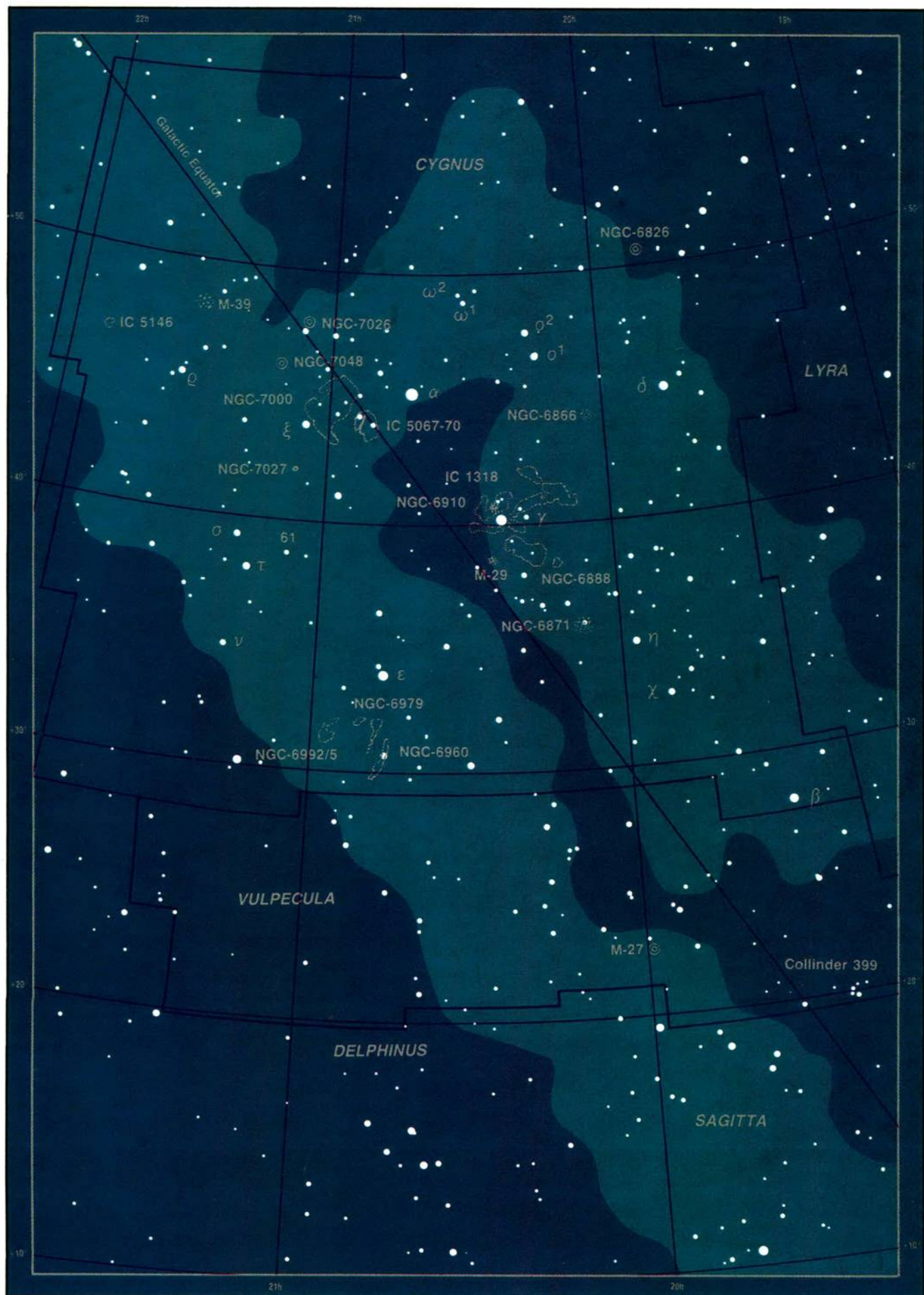
the Veil complex — detail reminiscent of photographs.

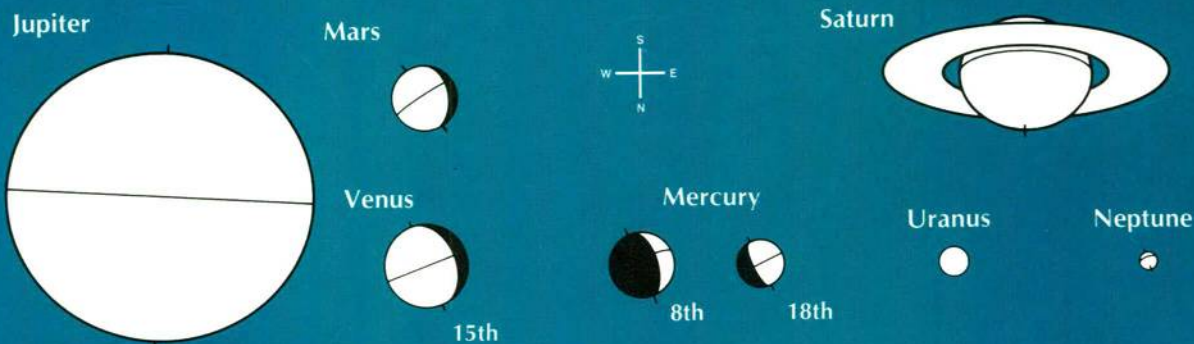
Beta (β) Cygni, known as **Albireo**, is one of the most observed double stars in the sky. Its magnitude 3.1 and 5.1 components are separated by a generous 34.3", making the system visible in small scopes. The most pleasing aspect of observing Albireo is the color contrast: a brilliant yellowish primary coupled with a dazzling soft-blue secondary. Albireo lies 120 pc distant; its stars are separated by 4400 astronomical units, or about 400 billion miles. Another notable double in Cygnus is **61 Cygni**, a pair composed of 5.3 and 5.9 magnitude stars separated by 28.4"; the distance to this pair, which was the first star to have its distance determined (by F.W. Bessel in 1838), is 3.4 pc.

A beautiful object is the bright and famous planetary M-27 (NGC-6853), the **Dumbbell Nebula** in Vulpecula, whose high-surface-brightness disk is easily visible in any telescope. This nebula measures 480" x 240" across and has an integrated magnitude of 7.3; binoculars show it to be a hazy little patch located inside a circular grouping of bright stars. A 6-inch scope under dark skies shows the dumbbell shape and perhaps even the "ears" of faint low-surface-brightness gas that extend outward. Larger telescopes show an extensive halo of nebulosity around the Dumbbell and the nebula's 13th magnitude central star, one of several stars floating inside the nebulosity (the others are foreground objects).

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★	★ ²	Double Star
Beta (β) Cyg		★ ²	19h 30.7m	+27°57'	3.1, 5.1	34.3"			LPV	Long Period Variable
NGC-6826		■	19h 44.9m	+50°31'	8.7	27" x 24"		10.6	⊙	Open Cluster
Delta (δ) Cyg		★ ²	19h 44.9m	+45°07'	3.0, 6.5	2.2"			□E	Emission Nebula
Chi (χ) Cyg		LPV	19h 50.5m	+32°55'	5.1-14.3	407d			□R	Reflection Nebula
NGC-6853	M-27	■	19h 59.6m	+22°43'	7.3	480" x 240"		12.0	SNR	Supernova Remnant
NGC-6866		⊙	20h 03.7m	+44°00'	7.6	8.0'	129	10....	■	Planetary Nebula
NGC-6871		⊙	20h 06.7m	+35°51'	5.2	40.0'	66	7...		
NGC-6888		SNR	20h 12.5m	+38°25'	11	18' x 12'				
IC 1318		□E	20h 16.5m	+41°48'		24" x 17"		2.3		
IC 1318		□E	20h 18.8m	+40°39'		50' x 25'		2.3		
IC 1318		□E	20h 19.8m	+40°07'		45' x 25'		2.3		
NGC-6910		⊙	20h 23.1m	+40°47'	7.4	8.0'	66	10...		
IC 1318		□E	20h 23.8m	+40°45'		85' x 50'		2.3		
NGC-6913	M-29	⊙	20h 24.0m	+38°31'	6.6	7.0'	81	9...		
IC 1318		□E	20h 28.5m	+39°57'		70' x 20'		2.3		
NGC-6960		SNR	20h 45.6m	+30°43'	7	70' x 6'				
IC 5067-70		□E	20h 48.6m	+44°22'	9	85'				
NGC-6979		SNR	20h 51.5m	+31°01'	11					
NGC-6992/5		SNR	20h 56.4m	+31°42'	7	78' x 8'				
NGC-7000		□E	20h 58.7m	+44°20'	4.5	120' x 100'				
61 Cyg		★ ²	21h 06.3m	+38°40'	5.3, 5.9	28.4"				
NGC-7026		■	21h 06.3m	+47°51'	11.8p	28" x 13"		14.2		
NGC-7027		□E	21h 07.1m	+42°14'	10.4p	18" x 11"				
NGC-7048		■	21h 14.2m	+46°16'	11.3p	60" x 50"		18.0p		
NGC-7092	M-39	⊙	21h 32.2m	+48°26'	4.6	30.0'	28	7...		
IC 5146		□R	21h 53.3m	+47°16'	9	10' x 10'		10.0		
Collinder 399		⊙	19h 25.0m	+20°00'						

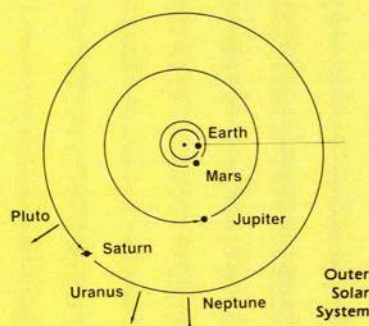
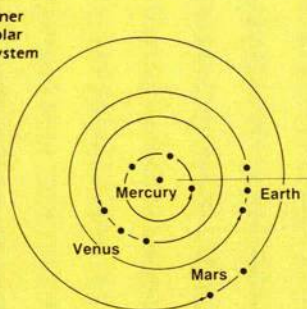
N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.





		Date	Distance (AU)								R.A. (2000.0)	Dec.
			Mag.	Angular Size	% Illum.	from:		Longitude:				
						Earth	Sun	Heliocentric	Ecliptic			
Sun		1	−26.7	31.8′	—	1.01	—	—	158°44.6′	10h 42.2m	8°13.0′	
		15	−26.7	31.9′	—	1.01	—	—	172°20.1′	11h 32.6m	2°57.7′	
		30	−26.7	32.0′	—	1.00	—	—	187°01.1′	12h 26.5m	−2°52.8′	
Mercury	♿	1	3.8	10.3″	3%	0.66	0.37	349°51.6′	152°12.1′	10h 14.1m	7°22.0′	
		15	−0.4	7.0″	52%	0.97	0.31	66°12.3′	154°21.7′	10h 27.2m	10°26.2′	
		30	−1.2	5.1″	95%	1.31	0.35	153°37.0′	178°02.6′	11h 58.2m	2°10.6′	
Venus	♀	1	−3.9	10.7″	93%	1.57	0.72	209°50.6′	179°16.0′	12h 01.6m	1°03.9′	
		15	−3.9	11.1″	91%	1.51	0.72	232°15.9′	196°27.1′	13h 04.2m	−6°06.6′	
		30	−3.9	11.7″	88%	1.43	0.73	256°08.2′	214°49.5′	14h 12.9m	−13°21.0′	
Mars	♂	15	0.1	8.6″	85%	1.08	1.40	302°07.9′	256°05.5′	17h 01.5m	−25°03.5′	
Jupiter	♃	15	−2.3	40.1″	99%	4.90	5.19	284°29.0′	273°04.5′	18h 16.3m	−23°29.4′	
Saturn	♄	15	0.7	15.8″	100%	10.50	9.89	227°17.8′	222°19.2′	14h 44.9m	−13°41.9′	
Uranus	♅	15	5.6	3.6″	100%	19.22	19.03	252°49.6′	249°25.0′	16h 33.8m	−21°56.9′	
Neptune	♆	15	7.9	2.2″	100%	30.13	30.26	270°33.6′	268°12.3′	17h 55.2m	−22°16.2′	
Pluto	♇	15	13.8	0.1″	100%	30.56	29.81	211°47.7′	210°04.8′	14h 17.2m	3°38.5′	

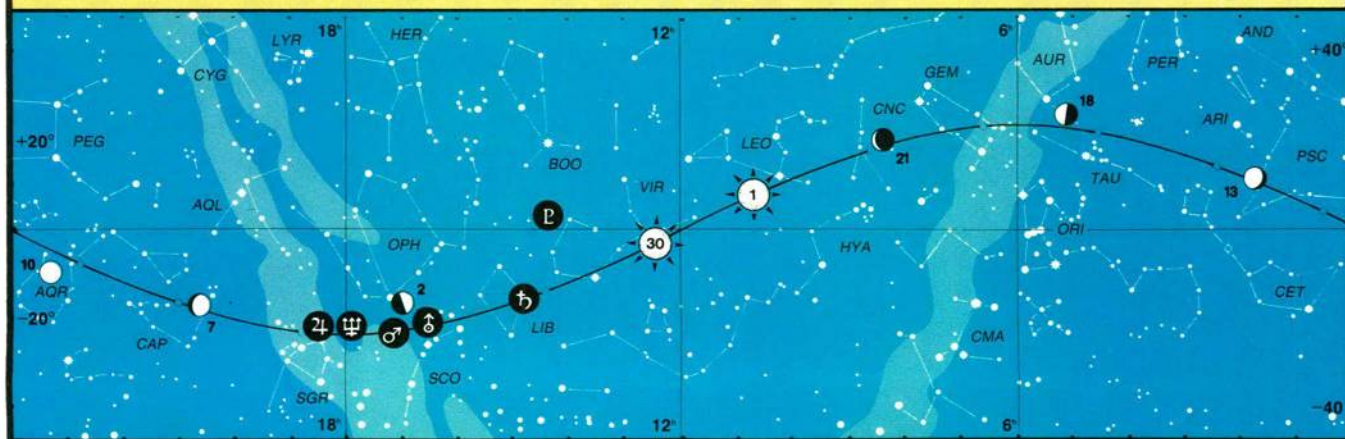
Inner Solar System



Outer Solar System

Moon Data

First Quarter.....Sept. 2 at 10:30
 Full Moon.....Sept. 10 at 7:01
 Last Quarter.....Sept. 18 at 9:31
 New Moon.....Sept. 25 at 3:11
 First Quarter.....Oct. 1 at 21:52
 Full Moon.....Oct. 9 at 23:58
 Apogee: Sept. 11 at 13:26.....406,374 km.
 Perigee: Sept. 25 at 2:51.....356,963 km.



Taken over three days (April 30, April 29, and June 1, 1984, top to bottom), these Mars photos by Jean Dragesco show how far Syrtis Major rotates in about three hours. The martian central longitudes are 286°, 309°, and 332°, respectively. His telescope was a 14-inch SCT; film, f/ratio, and exposure were unrecorded.

Mercury

Mercury's morning apparition this month is the year's second-best, but it's brief: between September 1st and 30th, the little planet pops up into view and sinks back again into the glow of sunlight. Greatest western elongation comes on September 14, and between the 8th and 22nd, Mercury will be at least 5° high, 45 minutes before sunrise.

Mercury will lie near the star Regulus for most of this apparition, but the pairing will be particularly close around the 8th, when the planet passes 1° 36' south of the star. Mercury's disk will then be 8.5" across, 21% lit, and at 0.8 magnitude (Regulus is 1.4).

Venus

Still extremely low, Venus will not be a good telescopic target during September unless you observe during daylight or evening twilight. Fortunately, its -3.9 magnitude makes it relatively easy to spot. If you have a low western horizon, try looking for it — your reward will be a glimpse of a gibbous disk 11" to 12" across and featureless white. As you look through the thick layers of air, Venus' image will shimmy and dance, all the while displaying many colors produced by atmospheric refraction.

Earth

The northern hemisphere's autumnal equinox occurs at 20:33 UT on the 22nd; this is the moment when the Sun's center crosses the celestial equator on its southbound journey toward the winter solstice on December 21st.

Mars

As the Sun sets earlier and earlier each evening, darkness catches Mars at nearly the same altitude and azimuth — about 20° high in the south-southwest. Mars is receding in the distance (it's now about 160 million km away), and its apparent size is steadily dwindling. Besides Syrtis Major (central on the disk at 5:06 UT on the 1st, and recrossing the martian meridian approximately every 24h 37m thereafter) and a polar cap, there are few other markings to greet you in your scope's eyepiece.

Asteroids

1 Ceres (magnitude 7.8) lies almost stationary in southwestern Taurus. Its positions:

9th: 3h 40m 5s, 10° 3.9'

19th: 3h 42m 2s, 10° 0.6'

Ceres rises at 10:30 p.m. local daylight on the 15th.

2 Pallas (9.0) reaches opposition on September 6th in north-central Aquarius. Its positions:

9th: 22h 45m 33s, 1° 42.8'



19th: 22h 38m 18s, -0° 29.9'
Pallas is visible all night long during September.

3 Juno and 4 Vesta rise too close to the Sun to be seen this month.

For convenience in plotting their positions in a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

As the sky darkens, Jupiter is the gleaming point of light above the Teapot of Sagittarius, low in the south. Although its elevation amounts to only some 20° to

30° (depending on whether you're observing from Canada or the southern U.S.), this is ample to let you get good views of the cloud belts on nights when the seeing is settled and steady.

Saturn

Saturn is rapidly sinking out of sight into the evening twilight. As its elevation lowers, the average seeing conditions naturally worsen and the less detail you'll be able to discern. See how long you can continue to make out Cassini's division, the broad dark line between the outer A



Right: September's "Best Astro-Photo" award goes to Scott Rosen of Van Nuys, California, for his photograph of M-20, the Trifid Nebula. He used an 8-inch SCT, hypered Fujichrome 400, a telecompressor, and a 30-minute exposure. Above: Alexander Brownlee caught spiral galaxy M-63 in Canes Venatici with a homemade 16-inch and hypered 2415 film. The exposure was 90 minutes.

ring and its inside neighbor, the B ring. On the 20th, Saturn will pass very close (5' north) to the 5.4 magnitude star Mu (μ) Librae.

Uranus

Moving slowly eastward, Uranus has a meeting with much more rapidly moving Mars on the 2nd, when the Red Planet passes $2\frac{1}{2}^\circ$ south of it. Uranus is a greenish-grey sixth-magnitude object in southern Ophiuchus, 4.5° north and about 8 minutes of r.a. east of Antares. Uranus is easily visible in your telescope's finder and displays a plain disk even at low powers.

Neptune

Smaller, more distant, and dimmer than Uranus, Neptune is still relatively easy to find and observe. Stationary in r.a. on September 6th (and moving eastward thereafter), Neptune lies a degree north of the Trifid Nebula (M-20) and about 8 minutes of r.a. west. Its eighth-magnitude disk is grey and measures $2.2''$ across.

Satellites of Jupiter				4:00 UT			
1	42103	.	..●.	16	4013	.	●..
2	40213	.	●..	17	41023	.	●..
3	1023	.	●..	18	42031	.	●..
4	2014	.	●..	19	32410	----	●
5	3204	.	●..	20	3042	.	●..
6	3024	.	●..	21	30124	.	●..
7	3014	.	●..	22	2104	.	●..
8	21034	..	●..	23	0134	●	..
9	02134	..	●..	24	10234	●	..
10	10243	.	●..	25	20314	●	..
11	201	.	●..	26	23104	..	●..
12	3420	...	●	27	30124	.	●..
13	4302	..	●..	28	302	.	●..
14	43021	.	●..	29	4210	..	●..
15	42103	.	●..	30	4013	.	●..

Jupiter = 0, Io = 1, Europa = Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)





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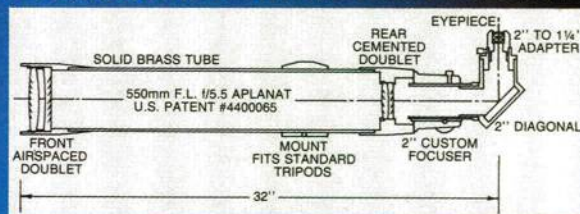
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